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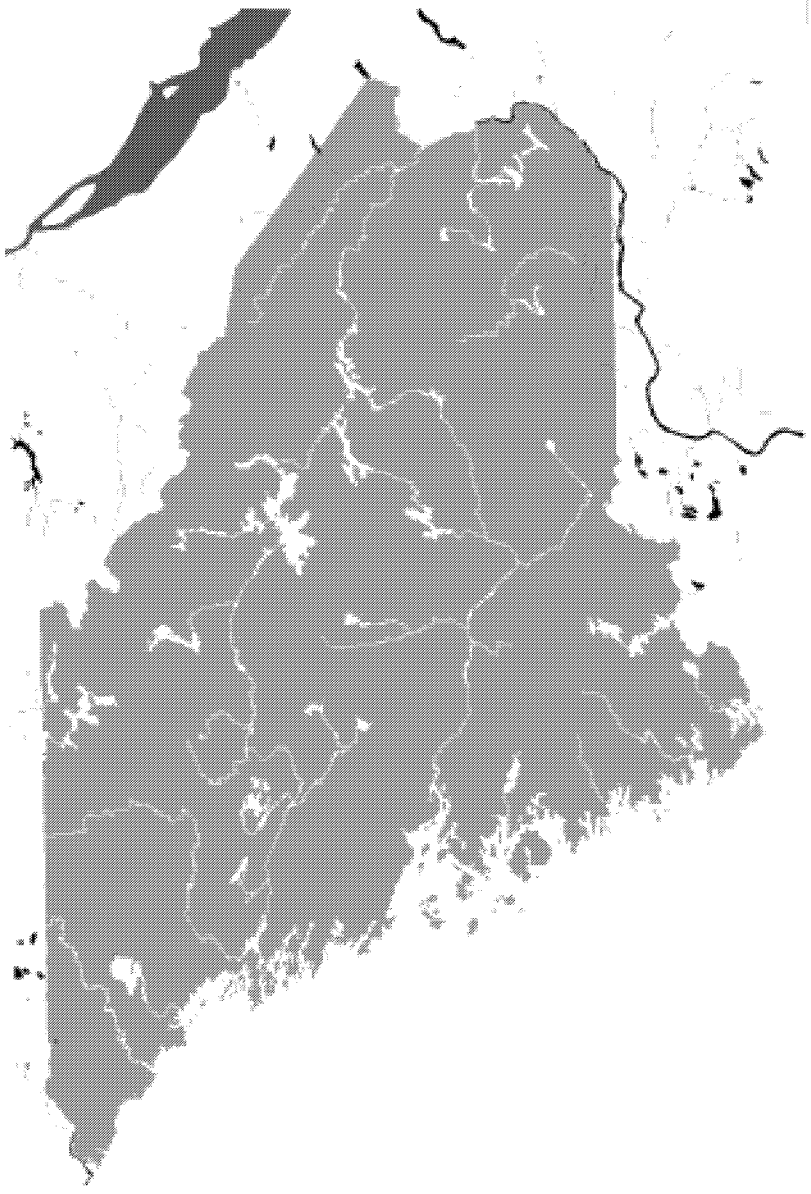
State of Maine Climate Change Action Plan, 2000

Maine State Planning Office

STATE OF MAINE CLIMATE CHANGE ACTION PLAN

Responding to Global Climate Change and Achieving Greenhouse Gas Emission Reductions in Maine:
Roles for Industry, Business, Government and Citizens



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Maine State Planning Office **University of Maine**

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STATE OF MAINE CLIMATE CHANGE ACTION PLAN

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PREFACE

This document addresses the complex subject of global climate change, its potential impact on Maine and the menu of policy options available to State government and Maine citizens. As the term "global climate change" implies, this is a worldwide problem that requires an international response. Although Maine cannot solve the problem alone, the State has an important role to play in helping Maine people to adapt to changes in our natural resources and to reduce the magnitude of future potential changes.

This report acknowledges three fundamental points:
1. SCIENCE: Scientific opinion, as expressed by the Intergovernmental Panel on Climate Change (IPCC), the American Geophysical Union and other professional scientific organizations, finds that "the balance of evidence suggests that there is a discernible human influence on global climate" (IPCC, 1995). Climate influenced trends such as receding glaciers, rising sea levels and increasing average global temperatures during the last two decades have been cited in support of that conclusion. Nevertheless, science proceeds from skepticism, and disagreement exists about the risk and probability of future climate change. Critics of the IPCC point to evidence that is consistent with a lack of warming and suggest that, in any case, rising levels of greenhouse gases have beneficial consequences.

2. VULNERABILITY: Maine's economy and environment are vulnerable to risks associated with changes in the climate. At this time, specific impacts are difficult to predict with confidence, and they may have positive and/or negative consequences for Maine's economy and environment. Maine is also vulnerable to changes in federal policies and to economic and social disruptions that may occur in other parts of the globe. Both action and inaction by Maine carry their own risks and benefits that need to be carefully weighed. Governments adopt policies to manage risks in a variety of other areas such as national defense, health care and crime. Policies that address climate change could protect the State from potentially adverse consequences associated with climate change.

3. POLICY: Federal law reflected in the Climate Change Protection Act of 1987, the Clean Air Act Amendments of 1990 and the United Nations Framework Convention on Climate Change (ratified under the Bush Administration in 1992) calls for voluntary approaches such as public education to reducing air pollutants, including CO_2. The Kyoto Protocol sets a target for reductions in trace greenhouse gas emissions from the United States at a level seven percent below 1990 levels by 2012. The Protocol has not been ratified by the U.S. Senate which has formally expressed opposition to key elements.

Climate change is not a new issue for Maine. In 1993, 135 natural resource managers, scientists and policy makers from New England and Eastern Canada assembled in Portland to consider the regional implications of global climate change and to develop state and provincial adaptation strategies. This first report focused on adaptive responses to climate change.

In 1994 Maine joined other states participating in the U.S. Environmental Protection Agency's State and Local Outreach Program which recognizes that state-level policies to control greenhouse gas emissions are essential for mitigating the potential economic, health and environmental threats posed by global climate change. The program is intended to help states evaluate these complex issues and to develop response strategies that address their distinct situations.

A Maine Climate Change Task Force (CCTF) was assembled to represent a broad range of interests: government, education, business and nonprofit organizations. In Phase I, the CCTF worked with the Maine State Planning Office and a team of scientists, economists

and policy analysts at the University of Maine to develop a Greenhouse Gas Emissions Inventory which was issued in August, 1995. The present report represents the work conducted in Phase II. It includes a suite of policy options designed to reduce those emissions, explanations of what those options would achieve and how they would be implemented. The costs of adopting them are also outlined. Phase III will involve implementation of a State Action Plan.

Responses to climate change fall into two categories: actions to limit greenhouse gas emissions, known as mitigation, and actions to adapt to a changing climate. This document focuses on the former. As noted above, it is a description of options, not a prescription for state policy. The actions identified in the report reflect the scientific knowledge and opinions of the Climate Change Task Force and do not represent the official position of any specific state agency or Task Force member. These actions are designed to give guidance and flexibility to policy makers.

During its discussions, the CCTF considered information from critics of the majority view as reflected by the IPCC. This viewpoint is perhaps best expressed by the Earth Greening Society (EGS), a private organization that supports advocacy and research. The EGS promotes the idea that the risks of climate change have been exaggerated and that rising CO_2 levels will benefit humanity. The CCTF recognized that while future impacts are uncertain, Maine should take a cautious approach by making reasonable preparations for potential negative impacts and reducing the state's contributions to greenhouse gas emissions.

The CCTF believes that in order to deal with an issue as complex as global climate change, we need to draw on the ingenuity and expertise of all sectors. Such an approach is proving fruitful at a national level as companies including United Technologies Corporation (owner of the Pratt and Whitney plant in South Berwick), Boeing, British Petroleum, Lockheed Martin, Maytag, and 3M have joined environmentalists and policy makers to address the problem in a way that sustains economic growth. In 1997 Sun Oil Co. (the company that markets Sunoco gasoline) acknowledged that "there is sufficient scientific concern about man made climate impacts to justify initiation of prudent mitigation measures now."

In summary, this report:

1) starts from the premise, as noted above, that appropriate investment in greenhouse gas mitigation is a form of risk reduction that is prudent public policy;
2) constitutes a starting place for further discussion and policy refinement in the public and private sectors;
3) promotes actions that have ancillary benefits such as increased energy security, resource conservation, and pollution and waste reduction;
4) suggests that the goal can be achieved in part through the expansion or completion of existing state and federal programs;
5) emphasizes that Maine should position itself to take economic advantage of potential future federal policies to limit greenhouse gas emissions; and
6) recommends a specific set of action steps for Maine to respond to the problem of climate change.

I. INTRODUCTION

This report addresses the issue of climate change and examines policy options that Maine and other states will have to consider as the United States forges a strategy for reducing and stabilizing greenhouse gas emissions. Climate change is not a new phenomenon in the Northeast. Indeed, past periods of glacial advances and retreats in New England occurred as a result of climatic changes. What is new and vitally important to Maine is the possibility of rapid and unpredictable climate changes that may result from recent increases of greenhouse gases in the atmosphere.

During the last century, concentrations of greenhouse gases such as carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons (CFCs) have increased rapidly in the atmosphere as a result of emissions from industrial and cultural activities (Figure 1). These atmospheric gases trap infrared radiation in the atmosphere and amplify the natural "greenhouse" effect. With increased concentrations of these gases, additional infrared heat is absorbed in the atmosphere, and excess energy becomes available to warm the Earth and to drive the hydrologic cycle. Environmental scientists predict that modern increases in concentrations of greenhouse gases will change the global heat budget and create unprecedented, problematic climatic changes across the biosphere from Maine to Malaysia.

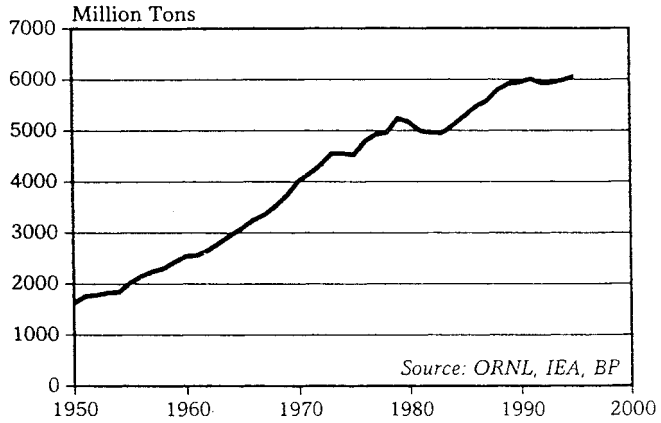

Figure 1. World carbon emissions from fossil fuel combustion during the period 1950-1995. Source: Oak Ridge National Laboratory, TN.

While it is recognized that many unknowns remain regarding the complex outcome of enhanced greenhouse warming and climate changes, there is a growing consensus around the world that major policy efforts are warranted to decrease greenhouse gas emissions and to minimize the potential risks of greenhouse warming and rapid climate shifts. In 1992, representatives of the United States along with more than 160 nations adopted the Framework Convention on Climate Change at the "Earth Summit" in Rio de Janeiro, Brazil. The objective of the Framework Convention is stated as follows:

"The ultimate objective of this Convention . . . is to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [human] interference with the climate system."

The Convention requires developed nations, such as the U.S. to undertake policies and measures to limit emission of greenhouse gases, but there are no compulsory targets. The Kyoto Protocol to the Framework Convention that was adopted in December, 1997 sets quantified greenhouse gas emission targets for developed nations. Developing nations do not have quantified targets. The Executive branch of the U.S. Government has signed the

Kyoto Protocol, but as with any international treaty, the U.S. Senate must ratify the agreement for it to have binding legal authority. If ratified by the Senate, our nation must cut back the large annual releases of greenhouse gases by 7% below 1990 emission levels based on the average of 1998-2012 emissions.

The President has subsequently urged all citizens to participate in the U.S. Climate Change Action Plan. Although many of the public policy responses to global warming must be initiated at the national and international levels, states have both the incentive and the ability to provide leadership in identifying policy solutions. Ultimately, for the U.S. to achieve its goal of reducing greenhouse gas emissions, Maine and other states will have to adopt policies that collectively lead to significant decreases in the release of carbon dioxide and other greenhouse gases.

This assessment report and action plan examines current and projected greenhouse gas emissions from Maine and presents options for reducing and stabilizing emissions of the state's primary greenhouse gas, CO_2. Per capita emissions of greenhouse gases from Maine are larger than those from every other state in New England, and Maine's per capita emissions of CO_2 from transportation are larger than the national average (NESCAUM 1999).

Maine is one of 37 states awarded grants in 1994 by the U.S. Environmental Protection Agency's State and Local Outreach Program to complete greenhouse gas emissions inventories and to develop comprehensive mitigation strategies for emissions reduction efforts. Maine completed the first phase of work involving a greenhouse gas emissions inventory in October 1995, and this report represents the completion of Phase II — identification of mitigation and adaptation policies to reduce greenhouse gas emissions. A third phase will focus on an education and outreach program concerning policies outlined in this report.

This report was produced cooperatively by the Maine State Planning Office, the Margaret Chase Smith Center at the University of Maine, and members of the Maine Climate Change Task Force. The Task Force membership includes representatives of state agencies, the business community, environmental science and policy professionals from the higher education community in Maine, and non-profit organizations. Over the course of numerous Task Force meetings and the public participation process, many diverse interest groups and perspectives contributed to the dialogue on climate change and to the review of a range of policy options aimed at reducing emissions of greenhouse gases and addressing the potential risks of climate change. It is the hope of the Task Force that this action plan will stimulate further public discussion and debate leading to the identification and adoption of policies that are effective and equitable.

Historically, Maine has been at the forefront of environmental protection and conservation, because its citizens have valued the quality of the state's natural resources and environment. Yet, recent problems with acidic precipitation and ground-level ozone derived from long-range transport of pollution have reminded Maine citizens that air pollution and global warming are problems that transcend political boundaries. These problems require cooperative efforts at the state, national, and international levels. Maine already participates in a number of energy and environmental programs such as the Climate Wise environmental audit program, the U.S. EPA Green Lights and Energy Star programs for energy conservation, the Clean Cities program for alternative fuels, Motor Challenge, and Renewable Energy Commercialization. The policy strategies examined in this report suggest ways in which Maine can meet its goal of reducing greenhouse gas emissions and use existing state, federal, and private sector programs as part of a successful implementation plan.

Maine, by being proactive, can help tailor any future federal emission reduction mandates to best suit our state. By being proactive, Maine can take advantage of potential economic gains from shifts that may occur in jobs, energy use, or technologies that result from GHG mitigation or adaptation. Our state is best served by taking an active role in shaping the state and federal response to global warming. Simply "doing nothing" and putting our heads in the sand is not prudent public policy.

II. BACKGROUND ON CLIMATE CHANGE SCIENCE AND POLICY

Global climate change

Global climate change is one of the most complex, challenging, and controversial issues facing scientists, policy makers, and the public. The root of the problem is that human activities have altered the balance of greenhouse gases in the atmosphere, so that we now face the risk of rapid global warming and climate changes that may threaten important features of our ecological, economic, and social systems. What is the prevailing view of the relevant facts concerning this issue?

It is important to begin a discussion of Earth's climate with an historical perspective. First, the proliferation of life on Earth through modern evolutionary time has been possible in part because of the natural greenhouse effect provided by water vapor, carbon dioxide, and trace amounts of methane and ozone in the atmosphere. Each year, a large fraction of the solar energy re-radiated from the Earth's surface is trapped in the atmosphere by these gases, thereby heating the entire biosphere. The warming effect of these greenhouse gases averts the frozen global climate regime that would prevail in the absence of a greenhouse effect.

A second important historical perspective is that climate changes have occurred many times before on Earth, as documented by the evidence of past ice ages, inland seas, and sedimentary geologic deposits. The causes of previous climate shifts are complex and have involved interactions among such factors as: variations in solar energy inputs to Earth; changes in the salinity and circulation of oceans; changes in concentrations of greenhouse gases, dust, or ash in the atmosphere; variations in the Earth's orbit; and changes in the surface reflectivity (the extent to which snow, ice and dry sands reflect sunlight) of the Earth. The potential significance of greenhouse gases in affecting global climate is demonstrated by the graph in Figure 2 showing a 160,000-year reconstruction of surface air temperature. As indicated, temperature changes over that historical period were closely correlated with changes in atmospheric concentrations of the greenhouse gas, CO_2.

Given that the greenhouse effect and climate change are part of the Earth's heritage, one might ask why there is so much concern about modern greenhouse warming and climate change. The short answer to this question relates to the magnitude and rate of recent changes in atmospheric chemistry. (1) Atmospheric concentrations of greenhouse gases emitted from human combustion of fossil fuels, industrial activities, and land clearing have increased dramatically during the last century. Carbon dioxide concentrations have increased more than 30% since the beginning of the industrial revolution. Concentrations of methane, a greenhouse gas with 22 times the global warming potential of carbon dioxide, have increased even faster to 140% of pre-industrial levels during the same time period. (2) With elevated concentrations of greenhouse gases, the atmosphere has gained an enhanced greenhouse warming potential. That means that more heat will be trapped in the atmosphere and that excess heat energy will contribute to warming of the Earth, changes in the hydrologic cycle, shifts in climate, and possible changes in major ocean currents. The major unknowns in this complex process relate to the timing and location of climate changes and the extent to which the intense warming potential associated with elevated greenhouse gas concentrations will be affected by other factors.

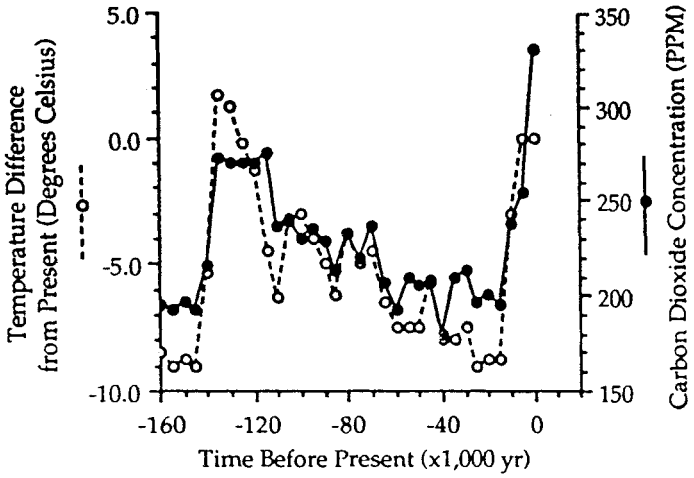

Figure 2. Relationship between atmospheric CO_2 and surface air temperature at Antarctica over the last 160,000 years. Data from Barnola, et al. (1987)

One of the most striking portraits of recent trends in global atmospheric greenhouse gas concentrations comes from the observations of CO_2 concentrations measured at Mauna Loa Observatory by Dr. Charles Keeling (Figure 3). Keeling reported that CO_2 concentrations have increased steadily from roughly 315 ppm (parts per million) in the late 1950s to 365 ppm in 1998. The data are a reflection of a global carbon budget that is no longer in balance, with releases to the atmosphere offset by removals from the atmosphere. Rather, there is an annual net transfer of CO_2 to the atmosphere, and that net accumulation of CO_2 is contributing to a growing greenhouse warming potential.

Figure 4 illustrates how the global carbon budget is characterized by tremendous transfers of carbon dioxide into the atmosphere by respiration and large removals of atmospheric carbon dioxide by plant photosynthesis and mixing into the oceans. Yet, despite the huge magnitude of those natural transfers of CO_2, the atmosphere gains an additional 3 billion tons of CO_2 each year from human fossil fuel combustion and deforestation, plus additional amounts of other greenhouse gases such as methane, nitrous oxide, and CFCs.

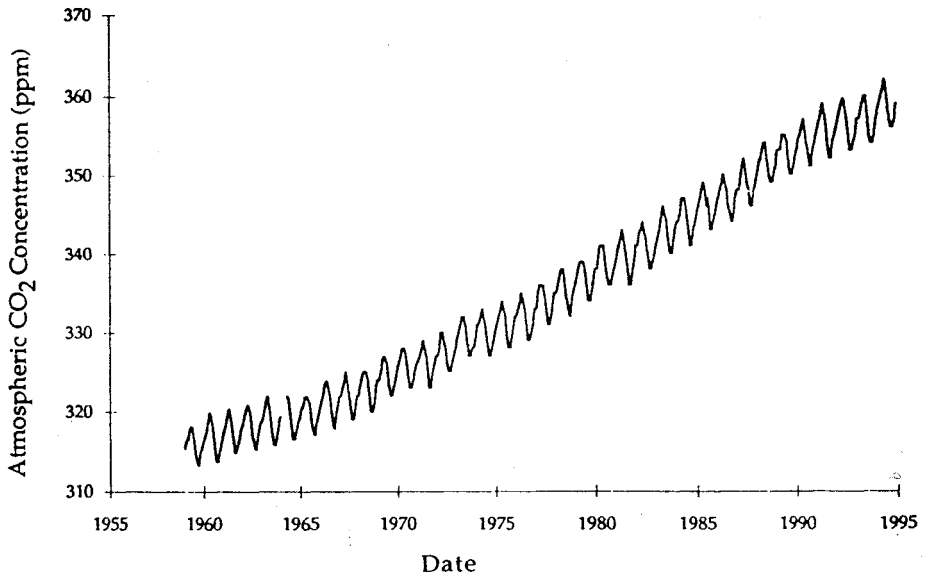

Figure 3. Modern trend of increasing CO_2 concentration in the atmosphere, as sampled by C.D. Keeling at Mauna Loa Observatory, Hawaii. The oscillations reflect the influence of plant photosynthesis and carbon storage during the growing season (troughs) and ecosystem respiration during the dormant season (peaks). Data provided by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy.

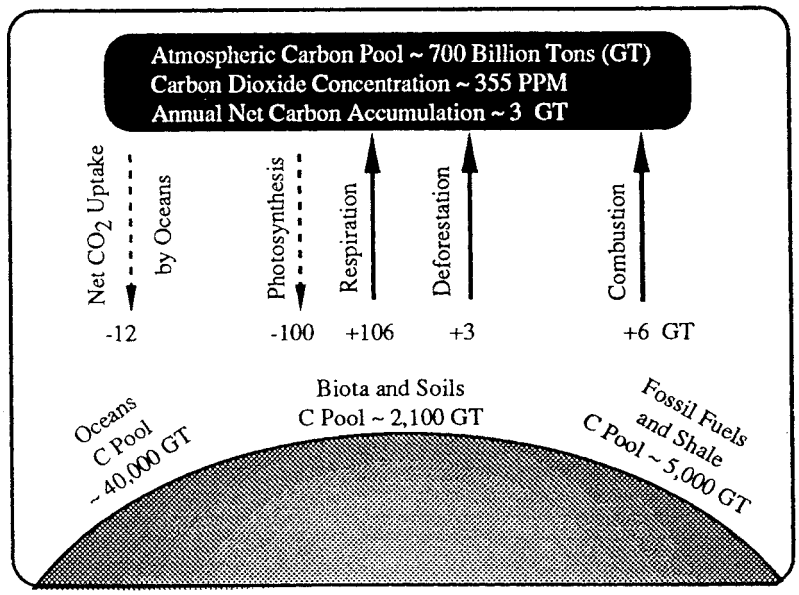

Figure 4. Estimated annual global transfers of carbon as CO_2 between the atmosphere and other storage pools on Earth. Removals from the atmosphere are indicated by arrows with negative values, whereas additions to the atmosphere have positive values. GT = gigaton (billion metric tons); PPM = parts per million. Data from Woodwell (1989); figure reproduced with permission from Cronan (1996).

In the absence of other compensating global processes and policy intervention, experts predict that the elevated concentrations of atmospheric greenhouse gases will raise mean

global surface temperatures roughly 1 to 3.5 degrees Celsius (2 to 6.5 degrees Fahrenheit) during the next 100 years (OSTP, 1997), and that the distribution of climatic zones and precipitation will change substantially across the Earth. Evidence of global warming has already been reported in the scientific literature indicating that surface air temperatures have increased an average of 0.5 degree Celsius since the late 19th century (Figure 5). This increase is well within the range of natural climate variability, and experts disagree about the role of human caused emissions of greenhouse gases. Weather records also indicate that 1990, 1995, 1997 and 1998 were the warmest years on record since 1866, and that the ten warmest years in the last 130 years have occurred in the 1980s and 1990s. The year 1998 was found to be the warmest year on record in separate reports released in January, 1999 by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA).

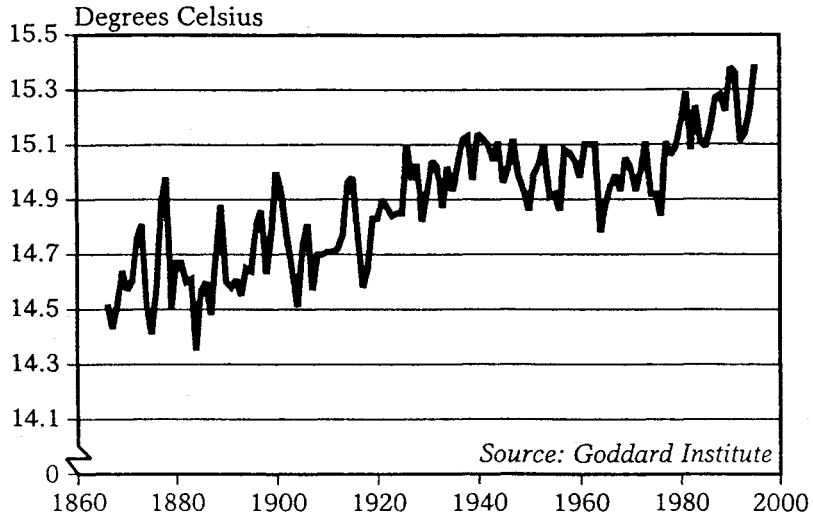

Figure 5. Average global surface air temperature during the period 1866-1995. Source: Goddard Institute and the Worldwatch Institute.

This brief section can be summarized with findings from the Intergovernmental Panel on Climate Change (IPCC) that was established by the United Nations Environment Programme and the World Meteorological Organization in 1988. The IPCC consists of committees of leading scientists from around the world whose task it is to review and to report periodically on the state of understanding concerning modern climate change. In its most recent report, Climate Change 1996, the IPCC concluded that scientific consensus supports the following statements: (a) there is a discernible human influence on global climate; (b) the Earth's climate is changing, with the result that the surface temperature of the Earth has increased over the last century, the last few decades have been the warmest in this century, sea level has risen 10 to 25 cm in the last century, and mountain glaciers have retreated world-wide in this century; and (c) without specific policies to reduce the growth of greenhouse gas emissions, the Earth's average surface temperature is projected by the IPCC to increase as much as 3.5 degrees Celsius by the year 2100, a rate of climate change that is faster than any climate warming trend over the last 10,000 yr.

Climate change and uncertainty

Climate is weather averaged over long periods — decades, centuries and millennia. Global climate is an extremely complex and chaotic system comprised of interactions and feedback effects among such factors as the atmosphere, solar energy, oceans, ice, the land surface, rivers, lakes and subsurface water. Uncertainty and disagreement arise concerning future climate changes because experts are trying to predict how a large complex, dynamic system will respond to a situation that has not occurred before in modern history. Since climate is chaotic to a certain degree, small changes in important parameters can cause unexpected, non-linear, and large results. Consequently, even though our understanding of climate change and our ability to make predictions about it will improve, we shall always be faced with elements of uncertainty when policy choices are made concerning climate.

Despite the uncertainties, serious consideration of policy options must begin posthaste. The costs of inaction are high and the longer the delay before action is taken, the more serious will be the consequences and the more difficult the ultimate solution.

The easiest way to relate to these uncertainties is to regard the projected ecological, socio-economic and human health scenarios as risks. In our everyday lives and in the policy arena, we deal with risks on a daily basis, assessing the probability of events and outcomes. Examples of such situations include health care, financial investments, engineering and defense — all situations in which we weigh the risks involved and hedge against disaster. We take out insurance policies on our cars and houses to protect ourselves from the unlikely, but potentially disastrous and financially ruinous risks. At a national level, governments invest in defense capacity not because of the certainty of conflict but because of the potential risk of conflict. If we approach the problem of climate change in the same manner in which we deal with other risks, then we can regard mitigation and adaptation strategies as insurance policies for our states, region, and countries. At the international, national and state levels we need to address questions about our knowledge of the risks, the levels of risks we are willing to accept and the actions we can take to avoid these risks. As John Browne, the chief executive of British Petroleum stated in 1997, the risks of climate change "cannot be discounted."

International and national climate change policy

The international community has been coordinating efforts to address the potential impacts of climate change for over a decade. In 1988 at an international conference in Toronto the focus was on the implications of climate change for world security. Representatives from 48 countries established a goal for industrialized countries to reduce carbon dioxide emissions by 20 percent by 2005. In the same year the Intergovernmental Panel on Climate Change was formed to conduct studies on global warming. The work included identifying emission sources, assessing possible consequences and developing mitigation strategies.

In 1990, at the United Nations World Climate Conference, the IPCC reported its initial findings. These findings became the basis for future international negotiations on a framework convention on climate change. At the United Nations Earth Summit in Rio de Janeiro, 154 nations signed the U.N. Framework Convention on Climate Change. The United States was the fourth nation overall, and the first industrialized nation to ratify the Convention. The Convention contained a legal framework that committed the world's governments to voluntary reductions of greenhouse gases, or other actions such as enhancing greenhouse gas sinks, with the goal of stabilizing atmospheric concentrations of greenhouse gases at 1990 levels. The Convention entered into force in March 1994, and

the parties held their first meeting in April 1995 in Berlin. They launched a negotiating process designed to produce a new legal instrument (either an amendment or protocol) to be adopted at their third meeting scheduled for Kyoto, Japan in December, 1997.

Prior to the Kyoto conference, the Clinton administration put forward a number of proposals committing the United States to a binding target of returning to 1990 CO_2 emission levels between 2008 and 2012 and to further reductions in the years following. The administration's plan comprised six main elements:

A. A proposal to enact tax cuts and to make research and development investments worth up to $5 billion over the next five years. These are targeted incentives to encourage energy efficiency and the use of clean energy sources.
B. Early actions by corporations to reduce emissions with the understanding that they will receive appropriate credit for their voluntary emissions reductions.
C. A market system for reducing emissions wherever they can be achieved most inexpensively, at home or abroad - a system similar to the experience with sulfur emissions trading.
D. A commitment by the federal government, as the nation's largest energy consumer, to reinvent how it buys and uses energy. This would involve the use of new technology, renewable energy resources and innovative partnerships with private firms and assessments of greenhouse gas emissions from major federal projects.
E. Increasing competition in the electricity industry and removing outdated regulations to save billions of dollars. At the same time, the U.S. leadership advocates reducing energy consumption by reducing waste heat.
F. Finally, preparation by key industry sectors of their own greenhouse gas voluntary reduction plans and government assistance in helping them achieve their reductions.

At the Kyoto conference, ministers and other officials from more than 160 countries reached agreement on a legally binding protocol under which industrialized countries will reduce their collective emissions of greenhouse gases by 5.2 per cent below 1990 levels. The 5.2 per cent reduction in aggregate emissions from developed countries will be realized through national targets that range between 6 and 8 per cent, and stabilization of emissions by other countries (Russia, New Zealand and Ukraine). Some countries (Norway, Australia and Iceland) may increase emissions by 1, 8 and 10 per cent respectively. The United States will be required to reduce its emissions by 7 per cent below 1990 levels. Unfortunately, the agreement does not place binding limits on the large projected emissions of carbon dioxide that will accompany further economic growth in China, Brazil, India and other developing nations.

The agreement grants countries flexibility in achieving and measuring their reductions. In particular a "clean development mechanism" will enable industrialized countries to finance emissions-reduction projects in other countries and to receive credit for doing so. An international "emissions trading" regime will be established allowing industrialized countries to buy and sell excess emissions credits among themselves.

In addition to reductions from various industrial and economic sectors, carbon dioxide emissions from deforestation and carbon dioxide reductions resulting from newly planted trees (which act as carbon "sinks" by absorbing CO_2 from the atmosphere) will also be factored into the equation. The protocol encourages governments to pursue emissions reductions by improving energy efficiency, reforming the energy and transportation sectors, protecting forests and other carbon "sinks", promoting renewable forms of energy, phasing out inappropriate fiscal measures and market imperfections, and limiting methane emissions from waste management and energy systems. It creates new incentives for

technological creativity and the adoption of "no regrets" solutions that make economic and environmental sense irrespective of climate change.

The Protocol was opened for signature for one year from 16 March 1998, and will enter into force after it has been ratified by at least 6 countries representing 55 per cent of the total 1990 emissions from developed countries. In the U.S. the president has signed the document, but the agreement will have to be ratified by the Senate.

Regional effects of climate change

At the regional scale in Maine, temperature trends over the last century are somewhat equivocal, with no clear warming or cooling patterns. The lack of a clear temperature trend for the Maine region may be the result of one or more of the following factors:

1) research-grade meteorological records have not been kept consistently in Maine;
2) the influence of maritime conditions in Maine may dampen the signal of warming compared to other regions;
3) it has been suggested that the warming potential of greenhouse gases has been offset in New England during the last 50 years by the influence of the regional sulfate aerosol haze originating from fossil fuel combustion.

There is other evidence besides temperature records, however, suggesting that Maine has experienced various symptoms consistent with climate change: measurable sea-level rise documented during the last century (those data are also affected by changes in land levels), and extreme weather events such as the drought of 1995, the 18" Portland deluge of 1996, and the 1998 ice storm that have all occurred in rapid succession.

Whether we reside in Maine or Kansas, it is important to remember that the patterns and effects of climate change are likely to vary considerably from place to place, with some regions experiencing more or less warming, or even regional cooling, and greater or lesser changes in precipitation. Unfortunately, climate models do not have the capability to predict regional climatic conditions with great accuracy. The IPCC does note, however, that climate simulation models agree on a number of features, such as: maximum warming in high northern latitudes in late autumn and winter, associated with reduced sea ice and snow cover; a reduction in diurnal temperature range over land in most seasons and most regions; a more active hydrological cycle; and increased precipitation and soil moisture in high latitudes in winter.

Global climate models have improved considerably over the years, but are still approximations of the real climate system. The spatial resolution is still rather crude — hence it is still difficult to speak precisely of impacts at the regional and state level. However, this does not justify a lack of discussion or action at the regional and state levels. While the principal focus of global climate change policy is at the international level, much thought needs to be given to the appropriate organizational level for the implementation of whatever international agreements are made. While some responses may be appropriate at the international and national levels, others will be more suited for implementation at the regional and state levels. For these latter cases, responses suitable to the economic, demographic and social characteristics of the state or region need to be developed.

The Conference of Eastern Canadian Premiers and New England Governors has already recognized this need. In 1990 a resolution at the 18th Conference of the New England Governors and Eastern Canadian Premiers directed the Committee on the Environment to

"develop a regional strategy on the global climate." In 1993 a total of 135 natural resource managers, scientists and policy makers from New England and Eastern Canada met to develop state and provincial adaptation strategies. In 1997 the region was also the focus of a regional conference on global change sponsored by EPA Office of Policy, Planning and Evaluation and Office of Economy and Environment.

The Northeast region is sufficiently homogeneous that it faces a common set of problems from climate change, sea level rise, and threats to natural resources. However, the economic variation of the region calls for a range of response strategies. The State Action Plans of Massachusetts, Vermont, New Hampshire, Rhode Island and Maine being developed under the auspices of the State and Local Outreach Program of U.S. Environmental Protection Agency's Climate Division are a further recognition of the need for the development of mitigation and adaptation responses at an appropriate level.

Maine Environmental Priorities Project

In 1996, the risks to Maine from global warming and climate changes were assessed as part of the Maine Environmental Priorities Project. In its report Consensus Ranking of Environmental Risks Facing Maine, the Steering Committee concluded that "compared to other environmental risks facing Maine, global climate change induced by human activity represents a medium risk, due to the potential for major changes to Maine's ecological systems from a warming of the earth s atmosphere and the attendant potential consequences to Mainers' health and quality of life." (Maine Environmental Priorities Report, 1996)

In recognition of the need to continue monitoring environmental risks, the Maine Environmental Priorities Council was established by Executive Order in May 1997. Its purpose was to be a forum for representatives of diverse public and private interests to evaluate current and emerging issues and trends regarding environmental and natural resource conditions and management. The first activity of the Council is the preparation of a State of the Environment Report on the current status of environmental issues for the Governor and the citizens of Maine. By June, 2000, the Council is to submit a revised comprehensive comparative environmental risk report to the Governor, which will include the risk associated with global climate change and its consequences for Maine.

Policy implications for Maine

Maine cannot effectively mitigate the risk of climate change problems alone. Nevertheless, in the hierarchy of local, national and international authorities, the State of Maine plays an important role in managing natural resources, building and maintaining future transportation systems, protecting human health and promoting economic development. In each of these areas, sound investments of tax dollars and private capital require that conditions be projected well into the future. Indeed, most of the benefits of today's investments in roads, water treatment plants, forest improvements and agricultural production will accrue under conditions that may be significantly different from those we experience today. While climate change may pose risks and opportunities that are highly uncertain, the State cannot afford to ignore them. Future generations will rely on our ability to adequately manage our public infrastructure and natural resource endowment.

III. REGIONAL AND LOCAL RISKS AND VULNERABILITIES

A large majority of scientists agree that climate change is an important environmental risk that merits international attention and action. However, experts also agree that the local effects of climate change are uncertain. The risks associated with climate change can be categorized as risks to natural systems, economic sectors and human health. Potential environmental impacts include global warming, loss of biodiversity, melting of polar ice caps, sea level rise leading to loss of coastal habitats, alteration of precipitation patterns, increased storm frequency and intensity, reduced soil moisture and changes in cloud cover (Manabe and Wetherald 1987; Pastor and Post 1988; Overpeck et al. 1991). On a global scale, among the natural systems which may be affected are water resources (decreases in per capita water availability in some areas), agriculture (hunger and famine in agricultural communities in parts of Africa, Asia and Latin America), and fisheries (vulnerability of national and local fisheries due to shifts in species mix and location).

Recent large damage claims from natural disasters have indicated that the insurance industry may face larger recurring payouts because of more frequent and larger disasters. Human health may be impacted by damage to habitats as a result of fires, floods, landslides, windstorms and other extreme weather events; heat related illnesses and death, and the greater transmission of vector-borne diseases as the ranges of insects and vectors expand.

At the 1993 meeting on A Regional Response to Global Climate Change: New England and Eastern Canada, it was concluded that the Northeast region of the United States faces a serious set of consequences from global climate change because of the patterns of settlement and the particular ecosystems that dominate the region. Tourism, recreation, fishing and the forest products industry are important contributors to the economy of the region and are vulnerable to the effects of changes in climate. Maine is typical of the northern states whose economies are strongly linked to natural resources.

Natural resources - forests and forestry

Forest resources are the primary natural resource of Maine and are central to Maine's economy. A larger portion of Maine's land surface is covered with forest than that of any other state (Powell et al. 1993). Further, more of Maine's forest (96%) is privately owned than that of any other state. According to Powell et al. (1993) 17, 533,000 acres of Maine's 19,753,000 acres of land were covered with forest in 1992. The forestry sector includes all activities that are involved in the growing, harvesting and processing of the physical products of the forest. Maine's paper making capacity is second only to Wisconsin's. The state also has numerous sawmills and specialty wood products mills, as well as a small but high-quality wooden furniture industry. Christmas trees and wreaths, maple syrup, baskets, and many other specialty products add value to the mix. As defined here forestry does not include forest-based recreation and tourism activities.

Maine's forestry sector produces goods and services valued in excess of $5 billion (including furniture and non-timber products, but not forestry services), and employs more than 30,000 people. Many service, trade, transportation and governmental activities could not exist without the basic production activities of the manufacturing industries. The value of production required from all economic sectors in Maine to deliver the output of the forestry sector, including direct, indirect, and induced effects, is approximately $8.5 billion (Field, 1996).

Maine forests will potentially be affected by climate change and may also contribute to climate change. Forest growth can be affected by changes in temperature, precipitation and storms associated with climate change as well as the incidence of pests and disease. Forests also play an important role in carbon sequestration. Hence, they can be part of mitigation policies. Conversely, the loss of forests contributes to increases in concentrations of CO_2. The manner in which forest management is conducted is, therefore, critical to climate change policies.

Climate change is one of a number of variables with the potential to affect forest ecosystems. Acidic deposition, tropospheric ozone, increasing concentrations of CO_2 and more invasive UV-B radiation can have significant and variable direct effects on forests. Increases in day and night time temperatures associated with climate change as well as disturbance effects of fire, insects and disease, severe storms and droughts could seriously affect the health of the forest.

We still lack the predictive capacity to state precisely how Maine's forests would be affected by a changing climate. What is important from a scientific and policy making perspective is the actual rate of climate change and the consequent rates of ecological response. Forests are vulnerable because of the longevity of trees and the length of time they take to reproduce. It is not easy for trees to respond quickly to environmental change. Neither is it easy to develop trees adapted to changed conditions. Hence, the effects of a rapid change in climate would likely be severe, as would the associated socioeconomic impacts on the communities dependent on forestry.

Recreation and tourism

Tourism and recreation are a major component of the Maine economy. In 1996 the value of the tourist industry in Maine was estimated at $3 billion. Expenditures were between $2 and $2.75 billion with another $300 million generated in state and local taxes. In Maine much of the tourism and recreation industry is concentrated in environments that are vulnerable to climate change, namely mountains and coasts. Although expenditures are derived throughout the year, many activities are seasonal and depend on a defined operating period to generate revenues. Anything that affects the duration of operating periods can seriously affect the viability of the tourist business. The sensitivity of outdoor recreation and tourism to such things as cold, wet summers or winters with little snow can be documented from the drop in revenues during bad years.

What is less certain is the effect of sustained changes in climate. It is likely that the industry can be adaptable in the long term. Short-term dislocations, on the other hand, may be highly disruptive. The extent of vulnerability will vary by the type of activity. Among those considered to be particularly vulnerable is the ski industry, currently worth approximately $100 million annually. During the mild winter of 1998-1999, the American Ski Company, which operates the Sunday River and Sugarloaf ski resorts, reported a drop in revenues in Maine. The warming of the climate consequent upon the predicted doubling of CO_2 levels would result in a loss of ski season days (for the adjacent state of New Hampshire this has been estimated as a loss of 10% to 20%). Given such a scenario there would need to be structural adjustments such as snow-making which is the most likely adaptive approach. An increase in this capability has already occurred in most New England sites as a response to recent warmer winters, and as a way of prolonging the season. Hence the ski industry could respond either to temperature swings or prolonged warming by supplementation of the snow supply through snow-making. The resulting

costs to the infrastructure budget could be substantial, endangering smaller or less financially stable firms.

Cold weather recreation activities that would be more vulnerable than the ski industry because of the lack of adaptive responses are snowmobiling, currently worth $261 million per year, and ice fishing, worth $226 million per year. The economic value of these activities, particularly to the retail sector, is often overlooked and underestimated. As can be seen from the associated revenue figures, a decline in these activities due to lack of snow cover and a shorter ice-on season could represent substantial losses.

Agriculture

In 1992, there were 5,776 farms in Maine, occupying an area of 1.26 million acres. As in other parts of the Northeast, farm numbers and farmland area have been declining for many decades. Just a decade earlier, there were about 7000 farms and the land in farms was 1.47 million acres. Nevertheless, agriculture is an important component of Maine's economy. The market value of agricultural products in 1992 was $430 million, split evenly between crops (including corn, oats, potatoes, hay) and livestock and animal products. Moreover, the value of marketed products has remained steady over time despite the decline in the farm numbers and acreage. Besides contributing directly to Maine's economy through sales of farm products, Maine agriculture helps to define and preserve the rural character of the state.

Identifying the probable impacts of climate change on Maine agriculture is greatly complicated by uncertainties about prospective changes in regional climate patterns. Climate scientists have difficulty predicting the global climate, much less conditions in Maine. In general, northern states may see increased yields whereas the South may lose production. In any case, agriculture is a highly managed system which is subject to decisions about factors such as planting dates, crop species, fertilizers and pest control. An emerging consensus among experts suggests that on balance, climate change will not diminish the ability of the United States to produce food for domestic and foreign markets during the next century (Adams, et al, 1999).

Even so, it is instructive to consider some of the possible changes, both positive and negative, that may have important impacts on Maine agriculture. On the negative side, warmer temperatures may increase problems with pests and diseases; indeed, the growth of the Maine potato industry in the late 19th century was due in part to the aphid transmitted disease outbreaks occurring in states to the south (Baron et al., 1993). Increased precipitation during the fall season may also complicate harvesting operations. Baron et al. note that autumns have been wetter than normal in recent decades. As a result, potato harvests have been compromised and, in some cases, ruined. More generally, changes in climate may influence the timing of frosts, cold exposure, heat stress, and wind. These factors affect the agricultural system, potentially in ways that greatly compromise its ability to function effectively; however, our understanding of these influences is incomplete (Stewart and Robichaud, 1993).

Climate change also has the potential to benefit Maine agriculture. Higher CO_2 concentrations may increase plant growth, thereby improving crop yields. In addition, longer growing seasons and warmer temperatures may enhance the value of farmland. Mendelsohn et al. (1994) predict that an increase in temperature and precipitation will elevate farmland values in some Maine counties, though other counties will be adversely affected.

However, similar to the damages from climate change discussed above, the possible benefits from climate change are highly uncertain. Mitigation efforts notwithstanding, it is critical that Maine agriculture be prepared to adapt to the variety of potential climate regimes. A central component of this strategy is to identify combinations of crop species and soil types that are best suited to altered climatic conditions (Stewart and Robichaud, 1993).

Coastal areas and sea level rise

The coastal areas of Maine are valuable assets, in terms of tourism, fisheries, and recreation, and as areas of desirable settlements, many of which contain valuable property. A recent report on sea level rise in Maine has verified that sea level has risen gradually in all of Maine's coastal municipalities during at least the last fifty years. A continuation of this historic rate of 2mm/year alone places many shoreline properties in jeopardy from coastal erosion and inundation. Concern exists about the implications of an accelerated rate of sea level rise as a result of global climate change associated with the greenhouse effect. If the predictions of the Intergovernmental Panel on Climate Change (IPCC) of a rise in sea level between 33 and 110 centimeters (13 to 43 inches) by the year 2100 are accurate, then Maine's coastal areas will face even more extensive threats to natural and built resources. In anticipation of such a possible rise, Maine has adopted a suite of "no regrets" policies (see Anticipatory Planning for Sea-Level Rise Along The Coast of Maine, U.S.E.P.A./Maine State Planning Office, 1995). The term "no regrets" means strategies that the state will not regret implementing even if there is no acceleration in the rate of sea-level rise, and that recognize that sea-level rise is just one factor affecting losses of coastal lands.

The key premises underlying the recommendations of the 1995 report are:

1) that the state should protect and strengthen the ability of natural systems to adjust to changes in shoreline position, and
2) that the state should prevent new developments which are likely to interfere with the ability of natural systems to adjust to changes in shoreline position.

It is worth noting that while the emphasis of the document on sea-level rise is on adaptation strategies, it also recognizes the importance of the state's contributing to policies that will help reduce emissions of greenhouse gases.

Tidal wetlands

One of the areas that will be directly affected by sea level rise is tidally influenced wetlands. The analysis conducted by the authors of Anticipatory Planning For Sea Level Rise Along the Coast of Maine states that the projected landward movement in shoreline position for "fringe" wetlands along bay shores ranges from 10 to 350 feet, depending upon the sea-level rise scenario. Any change in shoreline position is of concern because it may result in a substantial loss of critical wetlands — areas of important ecological and natural resource functions. Some of these functions are: providing essential nesting and feeding habitat for wildfowl and other wildlife; serving as a habitat for many rare and endangered species; providing nursery and spawning areas for many commercially-valued fisheries; contributing to the enhancement of water quality; and contributing essential natural flood control services.

The extent of loss in coastal wetlands will depend on their ability to migrate inland. That process, in turn, is affected by factors such as sediment supply, the composition of adjacent uplands, and barriers, either manmade or natural. There are more than 5,000 acres of salt marsh in the combined Casco and Saco Bay region, comprising approximately 20 percent of the regions' coastline. National studies suggest that 50 to 250 acres of coastal wetlands could be lost in Saco and Casco Bay even if marshes were allowed to migrate freely.

Marine and Estuarine Systems

Maine's benthic (seafloor) communities are more diverse than those of any other state on the U.S. East Coast. This high biodiversity is due in large part to the substantial substrate heterogeneity resulting from the retreat of the ice sheet at the end of the last glacial period but is due as well to the relatively low annual temperature range of the local waters. The biogeographic relationships of the biota of the Gulf of Maine and Nova Scotia are also made somewhat complex by the history of the region since the last glacial period. For example, many of the estuaries still harbor some species that are relicts of a period when water temperatures were slightly warmer than they are now. Most of these estuarine relicts are confined to inland reaches and are consequently isolated from other upper estuarine regions by the colder waters that prevail in the seaward areas of bays.

Any climate change that results in changes in water temperature will have a dramatic impact on these estuarine relict species. If the inland reaches warm, for example, one could expect the relict species to see an increase in habitat area, while at the same time the zone of colder waters would constrict slightly. On the other hand, were there to be a cooling of the upper reaches of Maine's estuaries, we would see the relict species gradually disappear, most likely due to their failure to reproduce.

Another group of species that might be influenced by changes in water or air temperature are those that inhabit the intertidal flats and rock surfaces. Long periods of elevated air temperature may cause reproductive failure in many of these species, but that is difficult to evaluate as they already survive a wide range of temperatures when alternately exposed to the air and water of the intertidal zone. In contrast, organisms living in tidal flats, while seemingly insulated from air temperature fluctuations, actually live in one of the most inhospitable of all habitats. On sunny days the temperature of the upper sediment layer may reach 44 degrees Celsius, and in the winter the sediment occasionally freezes. So it is unlikely that slight changes in temperature will have much direct impact on these species.

It is also unlikely that a small increase in water temperature would strongly impact the subtidal species of the colder reaches of Maine's estuaries. These species are not currently living near their thermal maximum, and, conversely, it would take a great deal of cooling to lower the annual thermal minimum of Maine's coastal waters. Most of these species reproduce when the waters are cool to cold, so a slight decrease in water temperature would have little impact.

The intertidal zone is most likely to be impacted by changes in sea level. Whether rapid or gradual, the change will occur over the course of many generations of intertidal species, thus allowing for continuous colonization of the newly available habitat. As available substrate type changes in area, however, there will be changes in abundance or dominance of some intertidal species.

Water resources

Maine is blessed with abundant water resources in the form of lakes, ponds, rivers, streams and groundwater aquifers. There are approximately 5,700 surface water bodies larger than one acre within the state of Maine (State of Maine Water Quality Assessment 1988), although some fraction of these are beaver ponds, swamps, or bogs. Maine's lakes cover about 5% of the state's area, and include 3,500 lakes larger than 10 acres (Kahl et al. 1991). In addition to lakes and ponds, it is estimated that the state contains 7,300 streams, with a combined length of 52,000 km (>32,000 miles). These surface waters provide valuable habitat for myriad wildlife species, and support a thriving outdoor recreation-based economy in Maine.

The potential impacts of climate changes on water resources in Maine include a number of possible conditions. Warming in the fall, winter, and spring could increase the length of the ice-free season (with impacts on ice fishing), whereas warming in summer could affect the availability of habitat for cool water fish species (to the detriment of sport fishing). Changes in precipitation amounts or the seasonal distribution of rainfall and snowfall could also have consequences for aquatic systems, changing runoff patterns in streams, as well as lake turnover and stratification patterns. Stream hydrology could shift toward a pattern of more extreme high and low flow conditions, or, alternatively, stream runoff could possibly become more evenly distributed throughout the year. Lakes could potentially become warmer and subject to more frequent drought-induced drawdowns, with adverse consequences for water quality and fishing. With annual economic activity associated with lakes and rivers in Maine estimated in the millions of dollars, the risks of adverse impacts on water resources from climate changes are worthy of ongoing consideration and attention.

In the above sections we have identified a number of key natural resources and dependent industries in Maine that potentially will be affected adversely by global climate change. Despite the scientific uncertainty surrounding the phenomenon of climate change, the magnitude of the potential negative impacts behooves state governments to examine a range of mitigation and adaptation responses. As was pointed out in the report on sea level rise, the impact of global climate change will be felt locally and the responsibility and associated costs of response planning will fall on state and local governments. Since knowledge about global climate change is evolving rapidly, a complete and definitive set of responses is unrealistic at this time. Nevertheless, an iterative process of developing and revising responses as more knowledge becomes available can be started.

Public health

Public health officials and physicians in Maine have identified both direct and indirect adverse health effects related to climate changes. Direct threats include the spread of insect-borne diseases, increased incidence of heat stress, respiratory problems and storm related injuries. Indirect threats occur as ecosystems adapt to new conditions and include development of favorable conditions for toxic marine algae and microbial contamination of lakes and rivers. While these effects are speculative at this time, recent events such as the spread of West Nile virus and Lyme disease and the frequent shellfish bed closures in southern Maine in 2000 underscore the importance of these potential impacts.

Some diseases that are now restricted to tropical and subtropical zones could spread to temperate climates. These include Rocky Mountain spotted fever, malaria, yellow fever,

Dengue fever, Ross River fever, encephalitis and hookworm. On the other hand, climate change could lead to a reduction in cold weather related health problems (Matyas, 1993).

Paul Liebow, a Board Certified Emergency Room physician who has practiced in Maine for almost 25 years, suggests that respiratory distress could become more common during the summer and lead to an increase in emergency room visits. Less severe symptoms may also appear more frequently in vulnerable populations, including young children and the elderly. A higher rate of respiratory problems could also occur if air quality is degraded by power plants that increase production to meet higher demand for air conditioning.

These potential health impacts could interact with the effects of stratospheric ozone depletion. A loss of stratospheric ozone could lead to an increase in ultra-violet (UV) radiation and a higher rate of skin cancers. Immune system suppression is also a predicted effect of increases in UV and could amplify the impact of increased exposure to diseases (Matyas, 1993).

IV. 1990 BASELINE AND PROJECTED FUTURE EMISSIONS

1990 baseline inventory of greenhouse gas emissions

A baseline inventory of greenhouse gas emissions from Maine was prepared for the Climate Change Task Force by Simmons and Bates (1995) using data compiled from the Maine State Planning Office and several other state and federal sources. Emissions estimates were prepared using standardized computational methods specified by the U.S. Environmental Protection Agency (US EPA 1995). Inventory estimates indicated that carbon dioxide and methane are the principal greenhouse gases originating from Maine, that total net emissions were approximately 19.6 million tons of carbon dioxide equivalents (CDE) in 1990, and that greenhouse gas emissions in Maine are dominated by CO_2 releases associated with energy consumption (Table 1.)

Table 1. 1990 inventory of greenhouse gas emissions from Maine based on estimates compiled by Simmons and Bates (1995). CDE=carbon dioxide equivalents

Source	Greenhouse Gas Emissions (tons CDE)	
Energy Consumption		
Residential		2,920,000
Commercial		1,490,000
Industrial		3,780,000
Transportation		9,030,000
Utilities		1,950,000
Subtotal		19,170,000
Industrial Cement Production		140,000
Waste Management		2,490,000
Agriculture		
Domesticated animals	217,000	
Animal manure	42,000	
Fertilizer use	20,000	
Blueberry cultivation	1,000	
Agriculture subtotal		280,000
TOTAL EMISSIONS		22,080,000
Land Use-Storage by Forest Growth		(2,470,000)
NET EMISSIONS		19,610,000

The large releases of greenhouse gases shown for energy consumption in Table 1 are in part a function of the variable carbon concentrations of different fuel sources. As indicated in Table 2, unit emissions of CO_2 from fossil fuels and renewable energy sources vary from near zero (for hydropower, solar, wind, and "renewable biomass") to values as high as 56.0 lb carbon per million Btu (for coal).

Table 2. Comparison of unit CO_2 emissions for different energy sources (in units of lbs. of carbon as CO_2 per million Btu).

Fuel	Emissions (lb. C/million Btu)
Coal	56.0
Residual oil	47.4
Oil	44.0
Kerosene	43.5
Diesel fuel	42.8
Gasoline	42.8
LPG (propane)	37.8
Natural gas	31.9
Biomass (sustainable harvest & re-growth)	0.0
Hydropower	0.0
Solar	0.0
Wind	0.0

Note that biomass releases about 42.8 lb. C per 100 lb. dry wood combusted, but that this carbon is recaptured over a 60-100 year re-growth period.

Greenhouse gas emissions from Maine can be compared to those from other New England states and from the U.S. as a whole. Maine's net greenhouse gas emissions of 19.6 million tons CDE (carbon dioxide equivalents) were smaller than those calculated for Massachusetts (93.4 million tons CDE) and Connecticut (45.5 million tons CDE), were roughly equal to New Hampshire (16.8 million tons CDE), and were larger than emissions from Rhode Island (10.35 million tons CDE) and Vermont (6.7 million tons CDE). Per capita emissions of greenhouse gases in Maine averaged 16 tons per person, compared to 22 tons per person for the U.S. as a whole. Other states in New England exhibited lower per capita emissions than Maine, ranging from minimum values of 9 tons per person in Rhode Island to values of 15 tons per person in Massachusetts. Per capita emissions of CO_2 from transportation in Maine (7.4 tons per person) were higher than the national average (7.0 tons per person) and were higher than all other states in New England (which ranged from 4.5 to 5.7 tons CO_2 per person). Presumably, the high transportation value is in part a reflection of the low density and high dispersion of the Maine population.

Because CO_2 is the dominant greenhouse gas originating from Maine, this report focuses primarily on the identification and control of CO_2 sources. In 1990, transportation was the largest source of CO_2 emissions in Maine, contributing 47% of the annual total of 19 million tons of carbon dioxide released by fossil fuel combustion in Maine (Figure 6; Table 3). Contributions of CO_2 emissions from other sectors were as follows: industrial (20%), residential (15%), electrical utilities (10%), and commercial (8%). In comparison, CO_2 emissions from energy use in the U.S. as a whole were dominated by electric utilities (36%), transportation (32%), and industrial sources (21%).

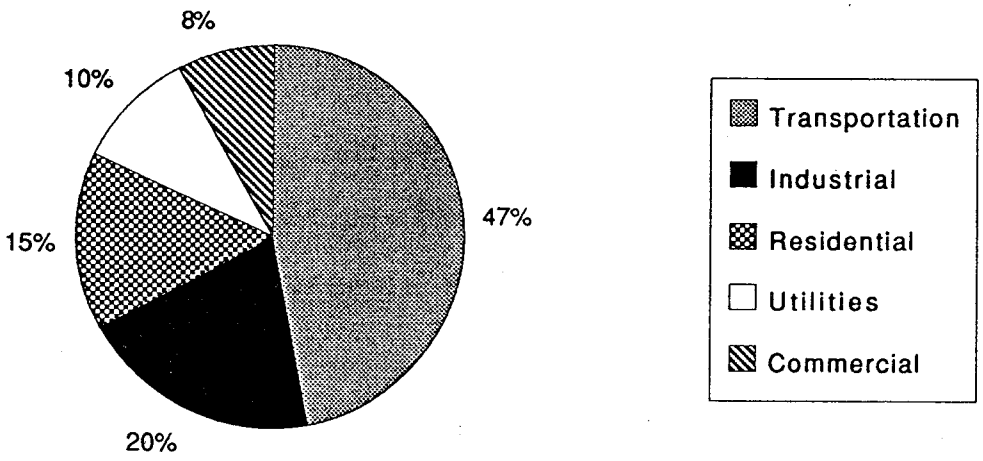

Figure 6. Relative contributions of different energy sectors to overall carbon dioxide emissions from Maine in 1990.

Table 3. Baseline inventory of carbon dioxide emissions from energy use in Maine for the year 1990. The value below each fuel source is the carbon content coefficient in lbs. of carbon per million BTU (MBTU). For each sector, the TBTU line shows energy supply from each fuel source, and the TTCDE line shows the carbon dioxide emissions associated with the fuel consumption. Biomass combustion, hydropower and nuclear power are assumed to contribute no net carbon dioxide emissions; emissions from electricity are allocated to fuels in the utility sector. Terms: TBTU = trillion BTU. TTCDE = 1,000 tons of carbon dioxide equivalents. N.Gas = Natural gas. Resid. = recyled oil. Kero = Kerosene. Biom. = Biomass. Hydro. = Hydroelectricity. Nucl. = Nuclear. Jfuel = Jet fuel. Dfuel = Diesel fuel. Gasol. = Gasoline. Elec. = Fuels in electric utility sector.

CO2 Emissions

Category		N.G as	Oil	Resid	LPG	Kero	Coal	Biom	Hydro	Nucl	JFuel	DFuel	Gasol	Elec	Tot E	Total TTCDE
C Coefficient		31.9	44	47.4	37.8	43.5	56	0	0	0	43.5	42.8	42.8			
Residential	TBTU	0.7	29.3	0	3.1	3.2	0.5	11.9	0	0	0	0	0	13.4	62.1	
Emissions	**TTCDE**	**40.7**	**2339**	**0**	**213**	**253**	**50.8**	**0**	**0**	**0**	**0**	**0**	**0**			**2896.25**
Commercial	TBTU	1.6	9.8	5.4	0.6	0.4	0.6	0	0	0	0	0	0	9.6	28	
Emissions	**TTCDE**	**93.1**	**782**	**464**	**41.2**	**31.6**	**61**	**0**	**0**	**0**	**0**	**0**	**0**			**1473.76**
Industrial	TBTU	2	4.1	30.5	1.3	0.2	5.5	17.7	12.5	0	0	0	0	16.2	90	
Emissions	**TTCDE**	**116**	**327**	**2623**	**89.2**	**15.8**	**559**	**0**	**0**	**0**	**0**	**0**	**0**			**3731.07**
Transportation	TBTU	0	0	0.9	0.1	0	0	0	0		14.4	23.6	76.4	0	115.4	
Emissions	**TTCDE**	0	0	**77.4**	**6.86**	**0**	**0**	**0**	**0**	**0**	**1137**	**1833**	**5934**			**8987.77**
Utilities	TBTU	0	0.11	22.3	0	0	0	40.8	27.8	52.5	0	0	0	0	143.5	
Emissions	**TTCDE**	0	**8.78**	**1918**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**			**1926.93**
Sum	**TTCDE**															**19015.79**

Projections for future emissions of carbon dioxide

Having compiled an inventory of CO_2 emissions from Maine for the baseline year 1990, the Maine Climate Change Task Force next examined a range of numerical model forecasts describing potential changes in CO_2 emissions associated with different moderate economic growth scenarios over the period 1990-2020. Two independent computer-based models (the ENERGY 2020 Model and the UM Matrix Model) were used to forecast CO_2 emissions resulting from seven different scenarios of future energy demand and variable fuel mixes (see Appendix D). The ENERGY 2020 Model is a sophisticated multi-sector energy analysis system that has been used extensively for energy planning in the utility industry. The UM Matrix Model was developed specifically for this project at the University of Maine in 1996 as a simplified multi-sector, multi-fuel energy emissions simulator. After successful inter-calibration of the UM Matrix Model with the ENERGY 2020 Model for a common forecasting scenario, the UM Matrix Model was used for subsequent forecasts of emissions scenarios. The baseline reference period for all model projections was 1990 when CO_2 emissions from energy use in Maine were 19.0 million tons/yr.

Projected CO_2 emissions for the year 2005 ranged among model forecasts from a minimum of 21.7 million tons/yr to a maximum of 26.3 million tons/yr (for a scenario that accounts for the premature closing of Maine Yankee nuclear power plant in 1997). The upper estimate of projected CO_2 emissions for the year 2005 exceeds 1990 emissions by 7 million tons/yr, which is a 38% increase over the 15-year period.

Projected CO_2 emissions for the year 2020 varied among model scenarios from 23.9 million tons/yr to a maximum of 32.1 million tons/yr (Figure 7), giving a range of 8.2 million tons/yr between minimum and maximum estimates among all 30-year forecast scenarios. The CO_2 emissions forecasts for the year 2020 generated by the ENERGY 2020 Model (Scenario I) and the UM Matrix Model (Scenario II) both agreed within 3% and were closest to the midpoint of the range of 30-year model forecasts (~ 28 million tons/yr).

Overall, model results indicated that under the most conservative emissions forecasting scenario, CO_2 emissions are expected to increase 14% from 1990 to 2005 and a total of 25% from 1990 to 2020. In the worst case scenario described in Appendix D, CO_2 emissions are projected to increase 38% from 1990 to 2005 and a total of 68% from 1990 to 2020. Based on the average or mid-point forecast of the ENERGY 2020 and UM Matrix models, emissions of CO_2 are projected to rise 40-50% during the 30-yr period from 1990 to 2020, reaching a total of approximately 27.5 million tons/yr in 2020. At that level of emissions, Maine's annual contribution to global atmospheric CO_2 will be approximately 8.5 million tons/yr higher than 1990 emissions.

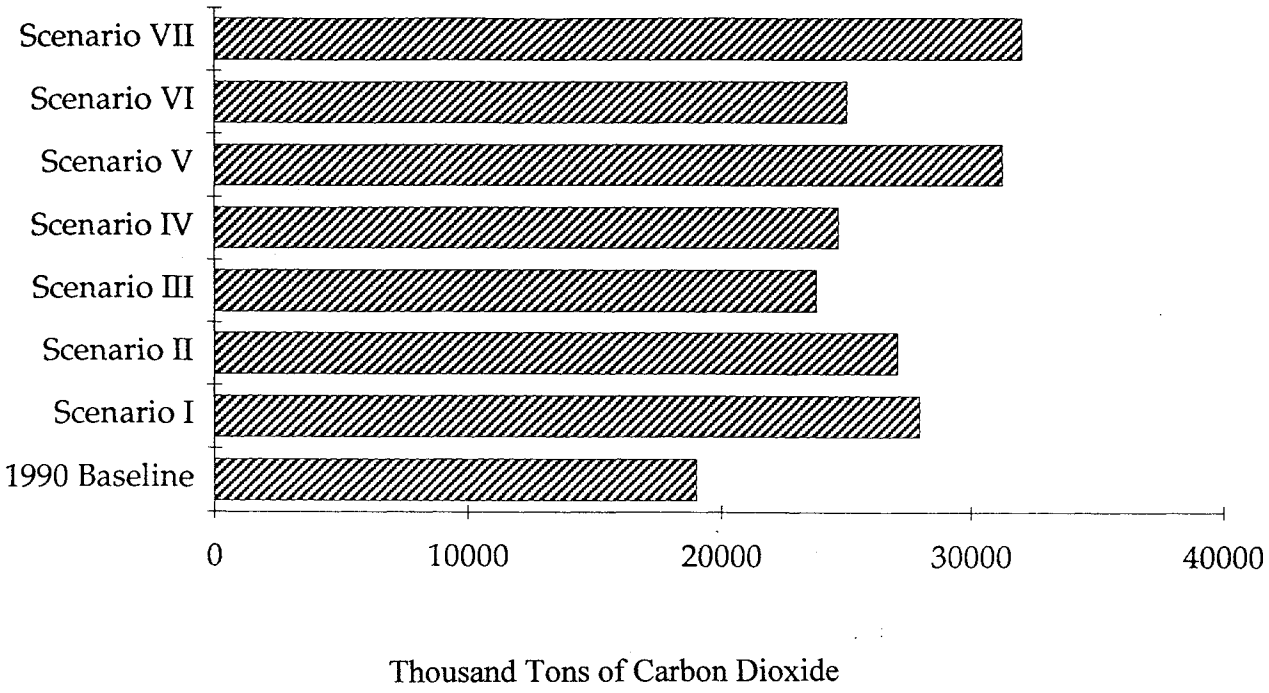

Figure 7. Comparison of model projections for CO_2 emissions from Maine in the year 2020. See Appendix D for explanation of scenarios.

V. GOALS AND TARGETS

Goal of the Maine Climate Change Action Plan

The goal of Maine's State Action Plan is to stabilize greenhouse gas emissions in the near term and, in the longer term, to decrease net carbon dioxide emissions to pre-1990 levels by early in the 21st century. These goals would be achieved through energy efficiency and conservation, fuel substitutions, carbon sequestration and technological innovations that minimize cost burdens and contribute to economic development and job creation consistent with sustainable environmental quality. Emissions reductions are targeted for transportation, electricity generation and use and industrial, commercial and residential activities.

Targets for emission reductions

Modeling projections indicate that annual emissions of Maine's primary greenhouse gas, CO_2, will increase above 1990 baseline values by as much as 7 million tons/yr by the year 2005 and by approximately 8.5 million tons/yr by the year 2020. As shown in Figure 8, annual emissions of CO_2 in Maine grow by roughly 250,000 to 400,000 tons/yr in response to increasing energy demand and fossil fuel consumption in the Maine economy. In order to offset current and projected increases in CO_2 emissions from Maine, policy measures beginning in 2000 will have to achieve incremental annual reductions (or sequestration) of CO_2 emissions on the order of 0.4 to 1.0 million tons/yr. Over the course of the next 7 to 22 years, the cumulative sum of these annual incremental reductions can bring Maine emissions of CO_2 back to pre-1990 levels.

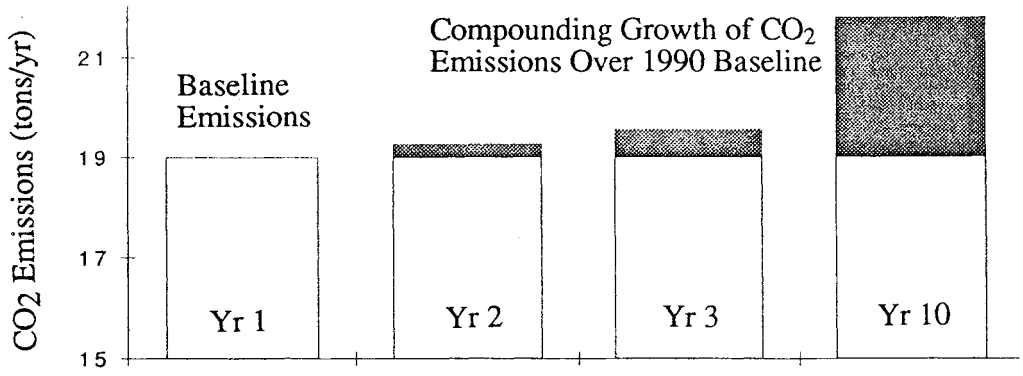

Figure 8. Illustration of the increment of additional CO_2 emissions added annually to the baseline emissions of 1990 in Maine. Mitigation strategies must offset or exceed that annual increment of growth in order to stabilize or to lower CO_2 emissions.

The target for this Action Plan is to decrease CO_2 emissions from Maine's total energy budget by 500,000 tons/yr beginning in 2000 and continuing every year until total annual emissions of CO_2 drop back to pre-1990 levels and are stabilized. This goal can be

accomplished through a combination of policies that 1) avoid or minimize CO_2 emissions from energy use or 2) contribute to long-term sequestration or storage of atmospheric CO_2. Specific targets for each sector are as follows:

Sector	Amount of CO_2 Avoided or Sequestered
Transportation	4.5 million tons/yr
Electricity Generation and Use	4.1 million tons/yr
Industrial	1.0 million tons/yr
Commercial	325,000 tons/yr
Residential	250,000 tons/yr

VI. IDENTIFICATION AND EVALUATION OF MITIGATION ACTIONS

The greenhouse gas mitigation planning process was guided by the Maine Climate Change Task Force, a broad-based committee comprised of representatives from state agencies, public and private interest groups, the business community, and program administrators from state government. The wide breadth of interests and expertise among committee members allowed for comprehensive discussion of issues and in-depth consideration of the impacts or consequences of potential mitigation policies. In addition to regular committee meetings, the Task Force used smaller working groups and larger facilitated working sessions with additional participants to permit critical review and prioritization of a lengthy list of policy options related to mitigation of greenhouse gas emissions in Maine. It was recognized from the earliest stages of Task Force deliberations that not all important perspectives were represented at the table and that policy recommendations from the Climate Change Task Force would only be finalized after thorough public discussion with all interested groups.

Development of selection criteria for screening mitigation policies

Prior to the evaluation process, qualitative ratings were provided for each policy option in terms of expected emissions reductions, investment by the cost-bearing sector, and the net impact on Maine's economy. These policy options were initially organized by sectors, including residential, commercial, industrial, transportation, and utilities. These sectors were later subdivided into coherent sub-sectors with specific goals. In order to evaluate these options, a matrix was produced listing sectors and sub-sectors on one axis and a range of evaluative criteria on the opposite axis. The screening criteria included the following factors (ranked as high, medium, low, positive/negative, or yes/no): emission reductions for a given policy; investment by cost-bearing sector; net economic impact on Maine; lifestyle impact; political feasibility; public acceptance; existing institutional capacity; private sector or public regulation; environmental trade-offs; and overall rank. High, medium, and low rankings were applied to emissions reductions and investments by cost-bearing sectors and the net economic impact was rated as positive or negative (see section on "Economic Analysis of Emission Reduction Strategies" for more details).

Members of the Task Force evaluated the options using a Lichert scale, and the modal values for each option were obtained (see Appendix A). Evaluations were conducted as an iterative process over a period of months, accompanied by detailed discussions and re-evaluation. This process led to the rejection or revision of a number of options and resulted in the range of options described in the policy options section.

VII. SELECTED POLICY OPTIONS

Introduction

This Climate Change Action Plan recommends a suite of policy options that, taken together, would accomplish the goal of emissions reductions.

These program initiatives and actions are refined from the longer list of potential actions considered by members of the Climate Change Task Force (CCTF). Presented as goals and actions, these policy options are intended to provide general direction and not specific steps to implementation. Each policy category has a goal or policy statement with some background information, a summary of existing policy efforts, and a listing of selected policy actions.

The original list of policy options from the June, 1998 working draft is contained in Appendix A, for reference and continued discussion. The summaries of emissions reduction estimates and economic impact assessments are contained in Appendix B.

These proposed state policy actions are founded on principles discussed by the CCTF and articulated by Governor King in his February 2, 1999 address setting an environmental agenda for his second term. They clearly focus on the important relationship between a strong and vibrant economy and the ability to improve environmental performance, including responses to global climate change. Indeed, in responding to often stated concerns about the economic impacts of climate change actions, an underlying theme of these policy suggestions is that Maine's future economic competitiveness may depend in large part on how well the State prepares for a future driven by increasingly efficient technology, changing environmental conditions and new public policies designed to reduce human impacts on the global climate.

Principles articulated by Governor King to guide the selection of policy options:

1) Options implemented by the State should reflect a long-term perspective, i.e., 25 to 100 years. This planning horizon recognizes that public investments in infrastructure (highways, bridges, water supplies, buildings, etc. . . .) often have lifetimes in that range and longer. As greenhouse gas concentrations persist well above pre-industrial levels, the environmental consequences of climate changes are also likely to persist into the foreseeable future.

2) State policies should set goals and leave specific methods for reaching those goals to the institutions and individuals responsible for achieving them. As climate change impacts occur, they are likely to affect Maine's economy and environment in ways that are difficult to predict with a high degree of reliability. The proper role of government is to steer the state along a sustainable path and, in doing so, support the creativity and energy of its citizenry who will take the necessary steps.

3) Given the uncertainty of future climate change impacts, State policies should err on the side of caution and, as far as practical, anticipate and prevent problems before they become significant. Experience with other environmental problems teaches us that prevention is always cheaper and more effective than remediation.

4) State policies should promote collaboration, not confrontation. Working together, businesses, citizen groups, farmers, fishermen, state and federal agencies, scientists

and others can move Maine forward more quickly than we can individually. Strong partnerships among interest groups are essential to carrying out the options listed in this section and new options that will evolve from the creativity of Maine people.

5) A strong economy is an essential component of effective greenhouse gas mitigation strategies. If incomes and employment are falling, growth and development can be driven by short-term needs rather than long-term health. Maine's greenhouse gas emissions strategy should support and promote enhanced competitiveness and position firms to take advantage of opportunities in Maine and abroad.

6) International agreements are already leading to national programs that promote new technologies designed to reduce greenhouse gas emissions. Maine needs to position itself and help businesses take advantage of the market opportunities they present. State policies can respond to national programs in ways that will benefit the interests of the state.

Maine people have shown time and again that they can create economic growth by solving practical problems. This spirit was captured recently by George David, Chairman and CEO of United Technologies Corporation, which owns the Pratt and Whitney facility in South Berwick. He said, "Not only have we and our predecessors created wealth, we have also redefined again and again how we live and work and play and communicate and stay well and indeed how we approach our very lives. Technology is at the root of this, as is also a most basic belief that we can and will solve problems. Greenhouse gases are a problem, and it's time for the usual and effective American solution." (David, 1998)

Policy Options

The following stated goals and policy actions were chosen on the basis of three criteria: 1) they are likely to be effective in reducing and/or mitigating the impact of greenhouse gas emissions; 2) they are likely to be politically acceptable to Maine people; and 3) they are likely to strengthen the Maine economy. Each suggested activity is associated with an existing or proposed program assigned to a responsible authority to carry it out. This report offers recommended actions that are judged to be effective, feasible and economically beneficial.

Public Information and Education

The goal of a public information and education strategy is to increase public awareness and understanding of the threats of climate change, the potential consequences for Maine and the actions needed to reduce emissions or mitigate adverse impacts.

The State has historically used information, education and promotional programs to encourage environmentally responsible behavior by citizens and organizations. Examples include industrial and residential pollution prevention programs and efforts to promote waste reduction and recycling. These and other programs underscore the point that good communication will be essential for successful, collaborative approaches to greenhouse gas reduction and adaptation to climate changes. Public education will be especially important during the next decade and beyond as new research-based information becomes available, and Maine's economic and environmental circumstances change.

There is currently no organized comprehensive education program for global warming or climate change issues. Instead the issue is being incorporated into a number of related governmental and non-governmental public education efforts. Educational programs will continue to be delivered by diverse groups seeking to advance their own agendas. Without some coordination these efforts will lead to public confusion over conflicting and unclear information.

The following options are intended to raise awareness, improve understanding and promote appropriate actions. A comprehensive program of public education and information will need to be carried out through the coordination of programs already being conducted by a variety of organizations. Since these activities will not reduce greenhouse gas emissions directly, their effectiveness would be judged by how well Maine citizens are informed and able to use information to make decisions that contribute to a reduction of greenhouse gas emissions.

Policy actions:

a) *Create a Global Warming/Climate Change Education Coordination Council.* This Council could be a public/private partnership that would work to better coordinate the content and delivery of public information and education programs and to generally improve the effectiveness of those efforts. The council might oversee the addition of information about climate change and needed actions to existing public and private efforts to promote awareness about climate change, to promote fuel conservation and comparative fuel efficiencies of motor vehicles, support commercial and industrial participation in Climate Wise Programs, and to promote public transit and ride sharing opportunities.

b) *Establish Sustainable Technology Demonstration Centers* to provide opportunities for businesses and citizens to examine new technologies. The State Planning Office could work to create a consortium with the University of Maine System, Maine Technical Colleges, Maine Maritime Academy and the Maine Department of Economic and Community Development to establish Centers that will demonstrate state-of-the-art technologies to Maine citizens and businesses. Alternative energy, energy conservation, and transportation technologies could be shown. In addition, the consortium could build partnerships with federal agencies and industry to fund pilot studies and research.

Energy Conservation and Efficiency in Residential, Commercial and Industrial Sectors

The goal of these policy actions is to reduce greenhouse gas emissions associated with energy use in residential, institutional, commercial, and industrial end use sectors through the application of energy conservation practices and use of more efficient appliances and equipment.

Energy efficiency and conservation measures in all sectors reduce energy consumption and expenditures, and thus result in positive net economic benefits. In addition, business opportunities arise in providing the necessary equipment and services needed to achieve energy conservation and efficiency goals. A variety of government, nonprofit, and private sector energy efficiency and conservation programs and services are already in place and could receive increased emphasis, such as:

- Electric utility demand side management (DSM) programs;
- State residential and commercial building codes and practices;

- Appliance and equipment efficiency standards;
- Federal Energy Star and Climate Wise programs;
- Pollution Prevention programs;
- Non-governmental organization and private sector programs and services, such as Northeast Energy Efficiency Partnership and the Manufacturing Extension Program.

Increased emphasis on energy conservation will yield significant benefits for Maine people and businesses. Energy conservation activities can be "no regrets" actions that lead to reduced energy needs, savings in energy expenditures, improved competitiveness and new market opportunities. Many of the options considered by the CCTF achieve greenhouse gas emissions reductions by increasing energy efficiency and practicing energy conservation.

Policy actions:

a) *Create a comprehensive, coordinated energy conservation program* run at the state level and implemented through a variety of existing agencies and programs to reduce energy consumption and increase efficiency across all energy types and technologies in all end use categories. This program would take advantage of existing federal and state programs, leverage state resources, and position Maine to take advantage of new federal initiatives and incentives created to reduce green house gas emissions. This action would augment the new State Planning Office Electricity Conservation Planning Program.

b) *Support private sector capacity to implement higher energy conservation practices and standards in residential, institutional, and commercial building construction.* This effort could be a combined effort of Maine home builders and construction companies, appropriate state agencies and the Technical College System building trades programs supported with funding from the US Department of Energy (DOE) Building Codes program and DOE/EPA Energy Star Homes program.

c) *Create a five percent energy conservation challenge in the residential, commercial, industrial and government sectors.* The State Planning Office could lead this effort to achieve reductions in energy use through improvements in lighting, motors, insulation, heat recovery, co-generation and other technologies.

d) *Create financial incentives for residential energy conservation improvements.* The State Planning Office could work to create a rebate program and cooperative bulk wholesale purchases of timed thermostats, attic insulation, compact fluorescent bulbs and other items. Low interest loans could also be provided for highly efficient furnaces and appliances as well as storm windows.

e) *Promote the purchase and installation of high energy-efficient heating and hot water equipment* (furnaces, boilers, and wood stoves) in homes and buildings, emphasizing reduced carbon emissions, through such programs as the Maine Oil Dealers Association furnace replacement program, and the Northeast Hearth Products Clean Heat Exchange Program.

Alternative Energy Technologies and Fuels in Residential, Commercial and Industrial Sectors

The intent of policies in this section is to promote and support the application of alternative energy technologies and fuels in the residential, institutional, commercial, and industrial sectors so as to reduce the emissions of greenhouse gases associated with the use of carbon-based fuels.

Alternative energy sources are those which provide more energy per ton of greenhouse gas emitted. Often, they are not based on fossil fuels, the primary sources of carbon emissions from energy uses. Alternative energy sources include technologies and sources such as ground source heat pumps, fuel cells, wind power, solar power, and biofuels. These sources have several advantages. They are often renewable and locally available, and their use reduces the burning of fossil fuels when full life-cycle impacts are taken into account. The development and use of these energy alternatives contribute to business development opportunities by creating new markets for goods and services that draw upon Maine's natural resources.

Carbon dioxide emissions from the industrial sector represented approximately 20% of total CO_2 emissions from Maine sources in 1990, and are projected to increase 60% by the year 2000, when industrial sources will contribute 22% of total emissions from Maine. The large industrial contribution to CO_2 emissions results from the size and relative energy intensity of the industrial sector, the continued growth of the sector and the heavy dependence of industry on oil and coal energy sources. Demand for electricity is also large in the industrial sector, thus providing a driver for increased CO_2 emissions from the utility sector.

Carbon dioxide emissions from the residential sector represented approximately 15% of total CO_2 emissions from Maine in 1990. Although energy demand in the residential sector is projected to increase 16% by the year 2020, direct CO_2 emissions from the sector are expected to decline to about 8.5% of total emissions. The decline in residential emissions is expected to result from shifts away from oil-fired heating to natural gas, electricity, biomass, and alternative energy sources such as solar and wind, although this future will depend on the price competitiveness of these alternatives.

In the commercial sector, carbon dioxide emissions amounted to approximately 8% of total CO_2 emissions in 1990. By the year 2020, net contributions from the commercial sector will rise about 35%, but the proportion of total emissions will remain roughly constant at 7-8%.

A variety of mostly federally funded programs currently operates to support and encourage the development and use of alternative fuels and technologies. US Department of Energy programs support several Maine-based initiatives to promote alternative fuels and technologies, such as State Energy Program grants to promote solar and wind power applications, the regional biomass program grant to support biomass energy development, programs to promote combined heat and power applications, and support for biofuels development.

The development of cost effective alternative energy technologies and applications will need strong policy level support in the form of legislative direction and regulatory support. In addition, the development and use of alternative energy will require the availability of effective technical and assistance programs to support demonstration projects and widespread application of alternatives, possible incentives and subsidies to help get new

technologies established, and continued investments in research and development that will be needed to bring improvements and innovations into the market place.

Policy actions:

a) *Program support and technical assistance.* Expand and improve the capacity of existing programs to work with business and industries to implement cost effective applications of alternative technologies. Work to improve coordination and partnerships between state and federal agencies and the private sector to educate and train service providers, and expand capacity to serve business clients.

b) *Demonstration projects.* Promote and support alternative energy demonstration projects, utilizing the existing network of programs and services as the stepping stone to widespread use of such alternative energy technologies as fuel cells, micro turbines, advanced wood chip heating systems, wind generation, solar heat and power and ground source heat pumps. These efforts could be supported by a low interest revolving loan fund program.

c) *Research and development.* Increase public investments in research and development support for new and advanced energy related technologies and their applications in Maine homes and businesses, as well as potential sales in national and international markets.

Business Opportunities and Competitiveness

State, national, and international business leaders have recognized the importance of addressing global climate change while sustaining a growing global economy. These leaders and others have come to realize that global climate change is "serious business," meaning that assuring a long-term healthy economy will depend on shared efforts to find solutions that benefit both the economy and the environment.

In keeping with building a sound Maine economy in a changing global marketplace, one goal of the Maine CCAP is to pursue policy options that will help improve the competitiveness of Maine business and industry in the global marketplace. A corollary goal is to identify opportunities and assist Maine businesses in providing the products and services that will be needed in the world market place to achieve greenhouse gas reductions. To achieve these goals, businesses will need access to market information, financial resources, including venture capital, as well as to entrepreneurial skills and technical assistance.

Maine is already positioned to take advantage of new regional and international business opportunities through existing programs and entities such as the Department of Economic and Community Development and its regional affiliates, the Maine Trade Center, and the work of the Maine Environmental Business Council. In addition programs like the Maine Chamber and Business Alliance's E2 Center, Climate Wise Partners program, the Industrial Assessment Center at the University of Maine, the Maine Manufacturing Extension Partnership, and the state's Pollution Prevention Program are providing technical services needed to help businesses to improve their manufacturing processes and to become more energy efficient.

Maine businesses are already changing their operations and making plans in light of climate change. Companies such as Guilford Industries, Pratt and Whitney and other businesses

are working as Climate Wise Partners to improve manufacturing performance and reduce energy consumption. This network of companies is working together as a peer group to share experiences and support efforts to meet internal environmental, health, and safety objectives.

Promoting a favorable environment for business growth is a key feature of Maine's ability to adapt to new conditions brought on by climate change. Such growth will require the development of commercialization strategies that include market analysis and sound business planning. Future business opportunities are implied in many of the options presented in this report, and in many cases, businesses will be the entities implementing energy conservation practices. The actions listed below focus directly on assisting and promoting new business activity.

Policy actions:

a) *Support and expand the Climate Wise Partners Program*, and work to include the State of Maine and its agencies as a partner.

b) *Create a public-private research and development partnership* under the leadership of the State Planning Office, Maine Science and Technology Foundation, Maine Department of Economic and Community Development and Maine Chamber and Business Alliance. Such a partnership could create and foster new business opportunities based on alternative fuels and energy conservation technologies. The Maine Technology Institute funded in the 1999-2001 state budget provides a useful first step in this direction.

c) *Develop commercialization strategies with expertise from Maine's higher education institutions and the private sector.* Such strategies could apply to new technologies in alternative fuel and energy conservation technologies such as gas turbines for co-generation, solar heating, photovoltaics and systems to remove carbon from waste streams.

d) *Create financial incentives for technology transfer and commercialization* such as tax credits for emissions improvements, early credits registry and credit trading programs. The State Planning Office could examine the barriers to business development for potentially high-risk innovative technologies and recommend changes in tax policy and business education to foster growth.

e) *Organize existing programs and organizations in an effort to better position Maine businesses to compete for new market opportunities.* Create a global warming/climate change business action plan to help shape policy and take advantage of market opportunities. Such an effort could be lead by the Maine Chamber and Business Alliance with PEW and industry leaders.

f) *Support Maine Chamber and Business Alliance E2 programs* as a public private partnership to provide energy and environmental services such as Climate Wise and Waste Wise programs to Maine businesses and industries.

Transportation

Similar to other energy use sectors, the goal in the transportation sector is to minimize greenhouse gas emissions associated with fossil fuel consumption in motor vehicles and

other forms of transportation. This goal can be realized by policy objectives to reduce fuel usage, improve vehicle fuel efficiency and increase the use of alternative modes of transportation and fuels.

Carbon dioxide emissions from the transportation sector represented almost half (47%) of total estimated greenhouse gas emissions from Maine in 1990. The enormous magnitude of CO_2 (and associated NOx, SOx, and VOC) emissions from transportation results from a combination of: (1) a large and ever increasing annual total of vehicle miles traveled (VMT), and (2) a relatively low average fuel efficiency (about 19 miles per gallon) for the population of cars and trucks in the state.

The policy objective of reduced emissions from motor vehicles can be achieved with a combination of the following strategies: (1) conserving fuel by reducing per capita VMT; (2) increasing the fuel efficiency of motor vehicles, and (3) substituting alternative "clean fuels" that emit less greenhouse gas per BTU of use.

Significant progress toward these objectives can be made by fully implementing those elements in the Maine Department of Transportation's transportation plans that promote improved transportation efficiency, reduced fuel consumption, and use of alternative fuels and vehicles.

Nevertheless, Maine cannot take unilateral action on one of the most important recommended policies in this section: vehicle fuel efficiency standards, also known as Corporate Average Fuel Efficiency (CAFÉ) standards (see Appendix F). These federal standards apply to each vehicle manufacturer's fleet of new cars and trucks. The Energy Policy and Conservation Act of 1975 established fines when the standards are not met. Recent research (DeCicco, 1995) concludes that annual increases in CAFÉ standards can significantly reduce carbon dioxide emissions. These types of reductions are particularly important for rural states like Maine which have minimal public transportation systems and whose citizens depend heavily on motor vehicles. Without improvement in this area, it will be very difficult for Maine to achieve significant reductions in greenhouse gas emissions.

Policy actions:

a) *Implement MDOT Transportation Plans to maximize potential emissions reductions* through the implementation of programs and activities that result in reduced fuel consumption. As an initial step, ask MDOT to prepare an estimate of potential reductions in GHG emissions that could be achieved.

b) *Work with municipalities, developers, and home builders to design and build more energy efficient patterns of development*, including well designed mixed neighborhoods, that reduce VMT and can support alternative modes of transportation.

c) *Work to develop a system of bikeways and public transit vans.*

d) *Establish educational programs* promoting public transit.

e) *Promote the benefits of ride sharing* in cars and vans.

f) *Enact a state fee bate program* funded by a gas guzzler surcharge on vehicle registrations.

g) *Support Clean Cities programs* as a means to introduce and promote alternative fueled vehicles in fleets and mass transit, when there are net emissions reductions.

h) *Work with MDOT and Regional Transportation Councils* to take maximum advantage of applicable sections of TEA 21.

i) *Cooperate with other states and Maine's congressional delegation to reform federal CAFÉ standards*, study the merits of having a single CAFÉ standard for cars and trucks, raise CAFÉ standards four percent per year from 2000 to 2010 and require the appropriate federal agency to determine if it is in the national interest to raise CAFÉ standards beyond 2010.

Electricity Generation

The policy goal is to minimize and decrease greenhouse gas emissions associated with the generation and use of electricity by shifting to non-combustion sources such as solar and wind, and to reduce the need for electricity generation through conservation measures such as demand side management programs.

Carbon dioxide emissions from electricity generation represented 10% of total carbon dioxide emissions from Maine in 1990, but they are projected to increase 3-4 times before the year 2020. At that time, emissions associated with electricity production may represent as much as 25% of total carbon dioxide emissions for Maine. The enormous increase in emissions derived from the generation of electricity will result from: (1) increasing economic growth and demand for electricity; and (2) the closing of Maine Yankee and subsequent replacement of nuclear power, a negligible source of greenhouse gases, by various forms of in-state or imported fossil fuel based power.

Since Maine is part of a federally regulated regional and national electric energy grid, these policy options seek to promote actions at the regional level and thus to avoid placing Maine businesses at a competitive disadvantage. Current efforts to restructure the electric utility industry have been under way for almost a decade. These include federal wholesale restructuring and systems management, state implementation of retail level competition, and the opening of new market place opportunities. Actions taken under restructuring do not necessarily account for climate change effects, but they may have a significant influence on energy conservation, alternative sources and environmental and economic effects.

Policy actions:

a) *Help to create a national program to allow for carbon dioxide emission permits trading*. The Governor could work with Maine's congressional delegation and other states to achieve this outcome without placing Maine's businesses at a competitive disadvantage. Carbon storage credits could be used as offsets to emissions as part of enhanced land management programs. (see Land Use section).

b) *Consumer information*. Provide information to electricity customers about greenhouse gas emissions from different sources of electricity as part of educational programs. To develop reliable information for consumers, promote a utility certification program based on carbon emissions and create favorable conditions for the establishment of extremely low emission sources such as wind and solar power.

c) *Develop a distributed system of Maine-based electricity generation facilities* using renewable and non-fossil fuel energy sources. Such a system could include fuel cells as well as wind power, photovoltaics and increased production from hydroelectric and biomass facilities. It is recognized that although nuclear power could some day play a role in reducing greenhouse gas emissions, significant technical and political hurdles make it an unlikely source of Maine's electricity in the foreseeable future.

Environmental Protection and Improvement

A significant opportunity exists to gain greenhouse gas reductions as a co-benefit of existing and evolving environmental protection and improvement programs at federal and state levels. The goal of policy options in this topic area is to maximize greenhouse gas emissions reductions as co-benefits associated with the implementation of existing and new environmental protection and management programs, especially in the state's air quality control programs, and solid waste management and recycling programs.

Ultimately, CO_2 emission standards and control regulations may become necessary to meet national and international emission reductions goals, but in the mean time, gains can be realized through the implementation of programs to reduce criteria air pollutants. In October, 1999, the State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) released a new report, "Reducing Greenhouse Gases and Air Pollution: A Menu of Harmonized Options." The report details technological and policy options for state and local governments to control greenhouse gas emissions while achieving substantial reductions in pollutants such as ozone (smog), fine particulate matter (soot), sulfur dioxide, and carbon monoxide. Some of the specific strategies noted in the report include:

- Switching to natural gas at existing coal- or oil-fired electric power plants.
- Replacing fossil fuels used for power generation with renewable energy (wind, solar, hydro, and biomass).
- Replacing fossil fuels used for power generation with fuel cells.
- Reducing electricity consumption via improved end-use efficiency.
- Reducing vehicle use by increasing such alternatives as carpooling, mass transit, and telecommuting.

In the future, new programs could be established to directly limit emissions of greenhouse gases from specific sources by setting standards through national programs. Such efforts would be consistent with international agreements on carbon caps and budgets that set the stage for credits trading, carbon offsets and other mechanisms. In this case, regulations should be written as to allow flexibility in achieving compliance, leaving the attainment of the standard to the imagination and ingenuity of those who must comply. CO_2 emission standards will be more easily maintained for large sources such as power plants than for small mobile sources such as motor vehicles.

Policy actions:

a) *Review and possibly modify existing environmental programs* to promote options that reduce greenhouse gas emissions while attaining the desired level of source pollutant control. The State Planning Office and the DEP could evaluate existing air quality, energy conservation, waste management, forest management, information/education and growth management programs to determine their impact on greenhouse gas emissions. Where emissions are being reduced as a consequence of the program, such efforts could be

expanded or tailored to achieve additional greenhouse gas emissions reductions. It is assumed that such modifications would comply with legislative and congressional laws and agency regulations.

b) *Work with Maine's congressional delegation* and other states to promote national and international programs that achieve greenhouse gas emissions reductions without placing Maine at a competitive disadvantage. Such an effort could promote the use of performance standards, emissions credit trading, and carbon storage offsets.

Land Use and Resource Management

Natural biotic systems can be a net source of CO_2 emissions and a sink in which large quantities of carbon can be stored. The balance between emissions and storage is greatly determined by changes in land use patterns and resource management activities. The goal of policy options related to land use and resource management is to reduce or avoid a net increase in emissions of greenhouse gasses that are associated with changes in land use and to optimize the storage of carbon in soils and vegetative communities as part of active resource management practices.

Land use patterns in Maine are changing. Spreading urbanization or sprawl, especially in the southern part of the state, is gradually reducing the amount of forested and agricultural land. Sales of forest lands in northern Maine could lead to shifts from forestry to recreation and residential uses, although the Land Use Regulation Commission (LURC) has adopted policies that create barriers to such changes. Moreover, agricultural land continues to be abandoned and allowed to revert to forest.

Growing forests in Maine are terrestrial carbon sinks in the global carbon cycle. Trees and other associated vegetation remove carbon dioxide directly from the atmosphere as they grow and store it in woody stems, foliage, and other herbaceous material. Additional stocks of carbon are stored in forest soils as organic matter accumulates on the forest floor. Forests also emit carbon dioxide through respiration and from decay and soil carbon oxidation processes. Over the length of a growth cycle, forest lands can sequester large amounts of carbon in standing trees and organic soil layers.

The amount of carbon that can be stored in Maine forests is influenced by the size of the forest land base, forest growth conditions, forest land use and management practices, and periodic disturbances from harvesting, wild fire, insects and diseases. Changes in forest conditions and the amount of forested lands will affect the ebb and flow of carbon storage and movement through the ecosystem, potentially increasing or decreasing net carbon storage. One major policy option is to design programs to increase carbon storage in soil, biomass and long-lived forest products.

Policy actions:

a) *Form a carbon storage management work group* to consider the design and implementation of biological management systems that incorporate a carbon storage function in the management of Maine's agricultural and forested lands. This would be the basis for carbon trading and offset programs.

b) *Support research and efforts to analyze the effects of different forest harvesting and land use scenarios* on carbon storage in soils, living biomass and wood products as the basis for designing effective forest carbon storage programs.

c) *Work with national or international institutions to establish a system of tradable carbon storage credits* to encourage landowners and wood processors to expand carbon storage on forested lands and abandoned fields and in long-lived forest products such as furniture and building materials. Such credits would be used for carbon emissions offsets based on the premise that net carbon transfers to the atmosphere would be reduced in the long run.

d) *Work to reduce the sprawl related loss of carbon storage capacity* in forests. Establish patterns of development that will contribute to a reduction in vehicle miles traveled, promote efficient transportation networks, and support alternative education, services and employment arrangements. Provide incentives for developments that are integrated with transportation systems, including walking and bicycle trails.

e) *Create a Great American Neighborhood Design Initiative* in the State Planning Office to emphasize the development of energy efficient neighborhoods that reduce vehicle miles traveled, allow the use of efficient district heating and cooling systems and reduce energy needs and costs to maintain livability and affordability.

f) *Promote tree planting in residential and commercial areas* as a means to sequester carbon dioxide and to reduce energy needs for heating and cooling. Energy use reductions could be achieved by properly locating trees and other vegetation to protect buildings from north winds during the winter and sun during the summer.

g) *Create a Local Communities Program* to link ongoing clean air, transportation and compact development initiatives with community and business development. The program could support collaborative efforts to site energy developments and foster carbon sequestration. This program could focus efforts to develop local energy supply networks based on renewable technologies and encourage development inside urban service areas.

Monitoring and Adaptation

The uncertainty associated with the timing and severity of the consequences of a rapidly changing climate argue for establishing ways to monitor oncoming changes and to be prepared to adapt accordingly. The goal of policy actions is to create an environmental monitoring network that can detect changes in key environmental conditions in a timely way that allows for the development and implementation of adaptive actions. A research agenda specific to Maine could be developed and supported so that information collected by a monitoring network can be properly interpreted. Such an agenda could come out of current efforts to understand regional climate change trends, such as the New England Regional Assessment being conducted by the United States Global Change Research Program.

Although this report focuses on policies for reducing greenhouse gas emissions, the State recognizes that the rise of greenhouse gas concentrations in the atmosphere is likely to result in some degree of climate change regardless of present actions. Data on sea level rise along the Maine coast, temperature trends in southern and northern Maine and the health and migration patterns of wildlife suggest that conditions are changing. The causes of these phenomena are not well understood. Sea level rise at the Portland tide gauge appears to be occurring at a rate that is faster than any in the historical record. Scientists have suggested

that recent changes in the health of Atlantic salmon and lobster populations may be related to climate, but these hypotheses have not been conclusively tested.

Nevertheless, these observations could foreshadow more dramatic changes to which the state will have to adapt. In 1993, resource managers and scientists from New England and Eastern Canada met in Portland to identify actions to help states and provinces adapt in six vulnerable economic and environmental sectors.

The conference assumed that the consequences of future climate changes could be both negative and positive for northeastern North America. Regional changes were also judged to be highly uncertain since some areas of the globe may experience regional cooling as others warm.

In general, the conference participants recommended that regional economies avoid dependence on a narrow resource base, promote flexibility and tailor future investments to avoid losses due to climatic extremes. Adaptation strategies could: 1) reduce risks to human health, ecological communities and economic infrastructure; 2) establish a review process for long-term capital investment to consider climate related risks; 3) re-examine public health system priorities to consider risks associated with temperature extremes and disease incidence.

Policy actions:

a) *A reassessment of forestry and agriculture policies*. The Maine Department of Conservation and the Maine Department of Agriculture could reassess current policies for their adequacy to adapt to influences created by climate change. Both forestry and agriculture draw upon carbon stores in the soil, and forest growth increases carbon stored in above ground biomass. Future management policies could encourage carbon storage by building soil organic matter on agricultural land and promoting tree growth. On the other hand, lengthening growing seasons, changing moisture patterns, changing relationships between crops and pathogens, etc. will require adjustments in public policies related to management practices, pest controls and new product opportunities.

b) *Programs to promote sustainable fisheries in the face of climate uncertainty*. The Maine Department of Marine Resources and Department of Economic and Community Development could develop policies to promote economic sustainability in the face of climate uncertainty. A combination of harvest fisheries and aquaculture in marine waters and catch and release and stewardship in freshwater could be encouraged. Options may be restricted by the present species mix for commercial and recreational fisheries.

c) *A program to encourage diversification in the tourism and recreation industry*. The Maine State Planning Office could foster diversification of the industry by identifying four-season recreational opportunities. Although the industry has demonstrated an ability to be adaptable in the long run, short-term adjustments could be disruptive. Greater collaboration between the public and private sectors could assure that Maine's portfolio of tourism resources remains competitive and attractive to the public.

d) *Development of engineering and planning standards* to assure that coastal infrastructure accounts for future storm surges and sea level rise. Sea level rise predictions could be used by state agencies, consulting engineers and municipalities in planning for coastal infrastructure development such as piers, roads, water treatment facilities and residential subdivisions. Planners, developers and municipal code enforcement officers

could have access to the latest information about sea level rise and shorelines vulnerable to erosion. Such information could be reflected in municipal building codes.

e) *Creation of a strategy to protect the natural evolution of Maine's ecological heritage* under changing environmental conditions. The state departments of Conservation, Inland Fisheries and Wildlife and Marine Resource could develop strategies for protection of natural heritage under climate change scenarios. Native species and their communities could be conserved through an ecosystem management approach. Elements include identification and cataloging of native biodiversity, a "protected areas" system, ecological monitoring programs, and research to understand stress-response relationships.

f) *Development of a long-term environmental and human health monitoring system.* The state departments of Conservation, Inland Fisheries and Wildlife and Marine Resources and the state epidemiologist could develop long-term ecosystem monitoring program including a suite of ecological indicators for climate change. This program could be integrated with federal programs for monitoring environmental trends. In cooperation with academic scientists and nonprofit public interest groups, indicators of climate could be selected for a continuous data collection effort. Such indicators might include ice-out dates on waterways used for commerce, temperature patterns, sea level rise, forest regeneration rates, the incidence of diseases such as Lyme Disease, or other illnesses transmitted by climate influenced vectors, and correlations between temperature extremes and hospital emergency room visits.

Carbon Management

The US Department of Energy (DOE) is also pursuing a more technology based approach for managing carbon emissions as a response to global warming and climate change concerns. The DOE recently issued a report on the fundamental research needs in carbon management. This report "identifies targets of opportunity for fundamental research likely to lead to the development of mid- to long-term solutions for reducing carbon dioxide concentrations in the atmosphere." One key line of research relates to technologies for capturing carbon dioxide (decarbonization), and CO_2 disposal and utilization.

Technology based solutions will not be acceptable to some interest groups, but they provide a course of action that can lead to significantly reduced atmospheric concentrations of CO_2, although, as with many other environmental issues, these solutions may simply transform one problem into another.

One policy action in response to the federal initiative is to work with the research and development community and appropriate Maine businesses to take advantage of announced grant availability to foster the development and commercialization of technologies to collect and transform carbon into useful products or place it in long-term storage.

Waste Management and Recycling

Significant amounts of greenhouse gas emissions can be avoided as the result of active waste management and recycling programs that encourage reductions in product and material usage, reuse of products, and recycling of wastes back into other useful products. The goal of climate change policy actions related to waste management and recycling is to

encourage and support improved waste management practices and to increase reuse and recycling to avoid the excess greenhouse gas emissions associated with manufacturing new products from virgin materials.

Many communities in Maine have a long history of supporting recycling and composting programs. In the late 1980s, the State actively began encouraging recycling programs at the municipal level. This effort was spurred in the early 1990s by a number of capital grant programs aimed at improving and expanding the recycling infrastructure throughout the state. An increase in the number and scope of programs, empowered by these grants, raised the possible participation level from 16% of the state's population in 1988 to over 95% by 1995. Amounts of recycled waste grew from under 100,000 tons in 1988 to over 556,000 tons in 1995. With increased recycling, there are marked reductions in greenhouse gas emissions that would otherwise result from the use of virgin materials and the incineration of wastes. It is estimated that a 5-10% increase in state recycling rates could decrease CO_2 emissions by as much as 70,000 tons of CO_2 per year.

Policy actions:

a) *Promote and expand existing programs as necessary*, including the State Planning Office Waste Management Plan and related programs. These include waste management rules and regulations and related pollution prevention programs in the Department of Environmental Protection; WasteCap/Climate Wise program in the E2 Center of the Maine Chamber and Business Alliance; recycling and waste management organizations.

b) *Integrate greenhouse gas emissions reductions* as a factor in awarding grants for local recycling and waste management programs.

VIII. PUBLIC PARTICIPATION PROCESS

The Maine State Planning Office hosted four meetings in May, 2000 to discuss the draft climate change action plan and receive comments from the public. Meetings were advertised in the *Bangor Daily News*, the *Kennebec Journal* and the *Portland Press Herald* and held at campus facilities of the University of Maine System in Presque Isle, Orono, Portland and Augusta. At each event, representatives of Market Decisions, Inc., consultant for the Maine State Planning Office, explained the purpose of the meeting, asked for comments and recorded individual responses. A representative of the State Planning Office attended each meeting and answered questions. A report was prepared and submitted to the SPO in July, 2000.

Total attendance at the meetings amounted to 95 people. Comments reflected a range of opinions from those who feel that the evidence for climate change is ambiguous and unclear as well as from those who feel that there is a significant and growing problem. No consensus emerged from the comments. Each meeting was the target of an informational picket by members of the Maine Property Rights Alliance.

People who are skeptical of the evidence stated that it is too early for the State to regulate fuel use or undertake special programs. Others were more critical and called the plan an "advocacy document" that did not include contrary points of view or provide a thorough review of the science on climate change. Some citizens who oppose state measures to reduce greenhouse gas emissions commented that voluntary actions by individuals, businesses and communities would be appropriate. Several speakers suggested that rural residents who depend on vehicles would be more seriously affected by fuel use reduction policies than urban residents. Documents submitted in support of such views challenged the theoretical basis for global warming and questioned evidence that average temperatures are increasing.

Other citizens praised the plan as a good starting point for state action on climate change and urged the Governor and the State Legislature to follow the planning exercise by implementing a program to reduce emissions in Maine. Some citizens who regard climate change as a serious threat called on the State to adopt more than a menu of options and instead embark on an aggressive program with measurable goals and a timetable. Others suggested that the State adopt a market-based strategy to encourage investment in energy conservation technology. Speakers raised concerns over potential impacts to public health and called on the State to place more emphasis on forest protection as a means of storing carbon.

IX. RECOMMENDATIONS

Vision and Leadership. Establish in state government a senior climate change administrator to direct, coordinate and implement the Climate Change Action Plan.

The following recommendations cover a suite of actions, which if fully developed would result in meeting the 1990 target for emissions of greenhouse gases from Maine sources:

Public Information and Education. Create an education coordination council to increase public awareness of the risks and potential consequences of global climate changes and the actions that can be taken to lower the risks by such means as energy conservation, motor fuel efficiency, alternative energy applications, and other actions.

Energy Conservation and Efficiency. Promote and support energy conservation and efficiency in residential, public, commercial, and industrial end use sectors.

Alternative Fuels and Technologies. Promote and support alternative energy technologies and fuels in residential, public, commercial, and industrial applications through technical assistance programs, demonstration projects, and research and development.

Business Opportunities and Competitiveness. Identify and capture business opportunities in the field of environmental technologies and services based on alternative fuels applications, energy conservation techniques, and newly emerging research in carbon dioxide control and management technologies and practices.

Transportation. Implement State transportation plans that reduce fuel consumption, promote energy efficient traffic and freight movement, support energy efficient patterns of development, and support alternative modes of transportation.

Electricity Generation. Work to reduce electricity demand through energy conservation measures and to shift electricity generation to lower or non-carbon fuels, such as solar, wind, and hydropower. Improve consumer ability to choose low or no-emission sources of electricity supply.

Environmental Protection and Improvement. Gain greenhouse gas reductions as a co-benefit associated with the implementation of existing and new environmental protection and management programs, especially in air quality control and solid waste management. Consider the use of generation performance standards, emissions credit trading, and carbon storage offsets.

Land Use and Resource Management. Work to promote and support land use and resource management practices that reduce or avoid the net release of GHG into the atmosphere. Incorporate carbon dioxide storage considerations into forest and agricultural management programs. Encourage patterns and densities of development that will support efficient use of energy resources.

Monitoring and Adaptation. Create an environmental monitoring network that can detect changes in key environmental conditions and allow timely adaptive actions, including reducing risk to human health and disruptions in economic and ecological systems.

Waste Management and Recycling. Increase the reuse and recycling of materials to avoid emissions of GHG associated with manufacturing new products from virgin materials.

X. IMPLEMENTATION

This Climate Change Action Plan is a significant step in the process leading to the implementation of actions that are needed to curb emissions of greenhouse gases from sources in Maine. The plan puts forth a set of recommendations for actions that are appropriate for Maine at this time and, when fully implemented, will result in lowering Maine-based GHG emissions to 1990 levels.

Additional planning and analysis will be required to implement the strategic course of actions recommended in this report. These recommendations suggest multiple roles for industry, business, government, and citizens, and successful implementation will require collaboration and partnerships within and across these sectors. Implementation needs to be carried out with regard for geographic, social and economic equity among Maine citizens.

Leadership

It will take strong leadership to move the state forward in responding to the threats of human induced climate change. Leadership will need to be exercised by individuals and organizations in all sectors of society and the economy to achieve the collaboration that will be needed to forge consensus on specific actions, timetables and responsibilities.

With broad public support government can lead and facilitate actions, but citizens and business will need to do their part. Government can assure that actions are created and carried out, and the plan anticipates a strong public sector role of leadership and coordination. However, many of the actions that will reduce emissions will be carried out by business, industry and the general public. Individuals and organizations in each sector can initiate actions that lead to reduced GHG emissions as well as improved productivity, enhanced competitiveness and healthy society.

Roles for Government

This plan calls on state government to plan and coordinate activities in education, alternative energy production and consumption, transportation, land use and other areas of responsibility. Further, the executive branch has the opportunity to lead by example, while the legislative branch will need to formulate supporting policy and program direction.

Early gains can come from continued implementation of existing environmental, transportation and land use management programs. Many of the state agencies responsible for these programs have participated in the planning process and are fully aware of the co-benefits for GHG emissions associated with their programs.

In addition, Maine State Government can adopt more aggressive actions and even lead other sectors in some cases. For example, the plan suggests:

- a fuel cell demonstration (and the fuel to power the cell) as an alternative energy project;
- the purchase of new hybrid automobiles for the state fleet;
- implementation of the Maine Department of Transportation tourist transportation plan;
- commitment of the State as a Climate Wise Partner;
- renewal of state commitments to energy efficiency purchasing, recycling and waste management programs.

Beyond the ability of the executive branch to incorporate climate change considerations into existing programs, there will be a critical role for the Legislature to play in considering, accepting, and directing the establishment of new or expanded programs aimed directly at the climate change problem. This effort will require strong support from those directly affected and a general sense of support from citizens that action is needed.

Role for Business and Industry

Businesses can play a crucial role in serving the public interest in abating global warming and in their own self-interest in improving the bottom line by seeking improvements in manufacturing performance and energy efficiency in production processes and business operations. Furthermore, the Plan recognizes that programs and practices to reduce emissions and adapt to changing conditions create business opportunities. These include opportunities in the fields of environmental technologies, services related to the development and application of energy alternatives, energy management services, and in new research and development programs aimed at carbon dioxide control and recovery. Continued collaboration between the State of Maine, the Maine Chamber of Commerce, and the Environmental Business Council of Maine will find and take advantage of these opportunities. An important component of this effort is improvement in the capacity to deliver technical assistance to Maine industry to implement emission reduction actions.

Roles for Citizens.

Citizens will play a major role in two ways, first by supporting the formulation of strong public policy and secondly in their lifestyle choices and purchasing decisions that would shape the marketplace in ways that contribute to reduced emissions. Currently, non-profit organizations and various interest groups are playing a crucial role in expanding public awareness of Climate Change issues. Citizens will continue to have the opportunity through the political process and consumer demand to influence the course of action on energy conservation programs, alternative energy choices and private sector initiatives to provide more "climate neutral" products.

Next Steps: Opportunities for Action, Barriers to Action

The Plan recommends a variety of actions that can be undertaken by industry, business, government, and citizens. The leadership and initiative required to take a particular course of action will depend on the motivations and needs of the individual players. Perhaps the greatest single barrier to action by government is the high degree of uncertainty about the consequences of global climate changes and the apparent lack of strong public support for new programs, which serves to undermine the political will to take direct action at this time.

Clearly, Maine has an obligation to take what actions are necessary to curb emissions from in-state sources. However, as this phase of the planning process concludes, it has become clear that further substantial progress in implementing reasonable actions will not be possible until the national government sets a clear course for action. Until the national gridlock in Congress over global warming is broken and an international plan of action is in place, some caution is advisable in pursuing actions that would put Maine interests at a significant disadvantage in regional, national and global markets. On the other hand Maine needs to be in a competitive position to take advantage of programs formulated to reduce the risks associated with global climate change. For the time being, it has become a question of garnering the political support needed for taking action.

The Plan provides a number of strategic courses of action that make sense for Maine. It recommends actions that move the state incrementally and modestly ahead to reduce GHG emissions while maintaining competitiveness. The Plan is the basis of support for on-going actions in the public and private sectors, as well as, a guide for new initiatives. The key strategies of the plan are: (1) improving the knowledge and understanding of the impacts of climate change leading to greater support for actions; (2) achieving the co-benefits of GHG emissions reductions associated with energy conservation measures, improvements in environmental performance, and enhanced manufacturing processes.

The CCAP will be the basis for encouraging, supporting, and guiding climate change initiatives and projects in all sectors of Maine's society.

XI. SUMMARY OF ESTIMATED GREENHOUSE GAS REDUCTIONS FOR ALTERNATIVE OPTIONS LISTED IN APPENDIX A

For all of the potential policy options identified by the CCTF and listed by economic sector in Appendix A, an attempt was made to estimate emissions reductions that could result from implementation of the specific policy strategy. In the table that follows, the policy strategies have been ranked into categories of high, medium, and low emissions reductions. As indicated, some strategies provide a potentially large individual impact, other strategies require bundling with multiple other options to achieve large aggregate reductions, and yet other strategies are important for their contributions to general education and management of the mitigation process. The magnitude of the CO_2 savings is highly dependent on scenario assumptions (See Appendix C).

Table 4. CO_2 emissions reductions expected from alternative policies

Policy Option	Avoided or Sequestered CO_2 [tons/yr.]**
High Impact	
Raise federal CAFE standard to 40 mpg	4 million
Implement feebate program	200,000
Replace oil power with 210 MW windpower system	350,000
Replace oil power with 50 fuel cell generators	350,000
Replace 35-100 TBtu oil-fired electricity with gas	1 million
Set CO_2 emissions standard and market for credits	2.5 million
Require 30% renewable energy portfolio	1.3 million
Replace industrial oil-fired boilers with gas	200,000 +
Promote forest management for C sequestration	250,000+
Reforest 80,000 acres of pasture in Maine or Tropics	200,000 +
Medium Impact	
Subsidize alternate vehicles w/gas C tax & impact fees	150,000
Expand and upgrade hydropower	100,000
Set emissions standard for industrial energy use	100,000
Fund industrial green loans with carbon tax	100,000
Promote industrial Climate Wise audits	150,000
Conserve 5% of home heating oil	100,000
Conserve 5% commercial energy	100,000
Implement 10,000 4-person rideshares	100,000
Lower Impacts	
Promote clean/efficient vehicles	25,000
Implement MDOT Strategic Transportation Plan	50,000
Lower highway speed from 65 to 55 mph	50,000
Clunker car retirement lottery	3,000
Education program on fuel conservation	13,000
Require vehicle inspection & maintenance	10,000
Appoint oversight committee for transportation	1,000
Implement hydrogen fuel R&D program	50,000
Implement rural renewable energy program	50,000
Develop market for renewable energy credits/C offsets	50,000
Promote public transit	10,000

Identify car pool clusters with GIS	5,000
Tighten industrial building std. for energy efficiency	50,000
Subsidize bus transit	20,000
Promote large employer ridesharing	2,000
Promote alternative fuel bus partnerships	1,000
Expand feeder networks for bus systems	10,000
Raise highway tolls	1,000
Promote compact development	1,000
Promote bikeways	2,000
Initiate REVERSING SPRAWL campaign	75,000
Require 50% tree cover on new house lots	10,000
Initiate Consortium for Sustainable Transportation	5,000
Develop state CNG (natural gas) vehicle program	5,000
Promote EV transportation charged by solar/wind	1,000
Create market demand for wood ethanol/biodiesel	1,000
Expand Clean Cities program	50,000
Utility green investment financing program	20,000
Campaign for electricity conservation	5,000
Green marketing/pricing program	5,000
Green lights/green motors program	20,000
Governor's Awards for energy conservation	5,000
Encourage DSM policies for conservation	20,000
Expand commercial heat pump applications	10,000
Upgrade consumer off-peak heating/cooling technology	10,000
Support advanced wood gasification technology	2,000
Implement public-private R&D partnership	2,000
Establish Sustainable Technology Demonstration Centers	5,000
Initiate consumer education program for energy conservation	10,000
Pilot demonstration programs for home energy conservation	5,000
Test trials for industrial alternative energy	30,000
New generation of industrial woodchip heating	30,000
Installation of industrial solar heat/electricity	50,000
Provide incentives for residential energy conservation	30,000
Climate Change Lottery	1,000
Educational outreach on alternative technologies	4,000
Conserve 5% residential oil-fired electricity	50,000
Promote residential solar hot water	10,000
Promote residential solar PV and windpower	10,000
Promote distributed residential power sources	10,000
Promote wood pellet heating	10,000
Support wood stove retirement/change over programs	5,000
Encourage woody lawns	5,000
Promote residential tree planting program	5,000
Tax home fossil fuel heat energy	5,000
Tighten home building standards	5,000
Provide education/assistance for commercial conservation	25,000
Promote commercial conversion from oil to gas	20,000

** Avoided or sequestered emissions depend on various assumptions or scenarios

XII. ECONOMIC ANALYSIS OF SELECTED GREENHOUSE GAS EMISSIONS REDUCTION STRATEGIES

This section presents estimates of the costs of achieving greenhouse gas emissions reductions in Maine. Given the large number of potential strategies (see Alternative Policy Options), it is infeasible with the available resources to conduct a detailed cost analysis of each policy; furthermore, for some policies the relevant costs cannot be quantified. Our approach involves analyzing several policies in detail and surveying cost estimates in other state action plans that are thought to be similar to costs for programs in Maine. From these estimates, we categorize the remaining strategies in terms of probable costs (see Appendix B).

Costs may be calculated in a variety of ways. The recommended approach for climate change assessments is to estimate incremental costs associated with reduction strategies. Incremental costs measure the increase or decrease in costs relative to a baseline scenario reflecting economic conditions in the absence of the policy. Thus, incremental costs measure the *change*, or the increment, in costs corresponding to a particular reduction strategy.

Costs are a measure of the resources committed to achieve an economic outcome. Costs may be explicit, as in the case of expenditures for CO_2-reducing technologies, or implicit, as with the allocation of time to an activity that reduces emissions. In the latter case, there is an *opportunity* cost associated with the time that might have been spent on other activities. Costs can be positive or negative. When they are positive, they refer to a reduction in available resources (e.g., money, time). When they are negative, there is an increase in available resources. For instance, an energy efficiency strategy may require positive costs initially for new equipment, but negative costs over time related to lower expenditures on energy. The *net* cost is the sum of positive and negative costs.

Emissions reduction strategies are likely to impose costs, both positive and negative, on many sectors of Maine's economy. For this analysis, we present two cost estimates. The first measures the cost borne by the targeted sectors. This is the outlay of resources by sectors that are the focus of an emissions reduction policy. Continuing the example of an energy efficiency strategy, the targeted sectors are those that purchase the energy-saving equipment. Their costs equal the purchase price of the new equipment less any savings from lower fuel expenditures. Some policies may take a number of years to implement, in which case a share of the costs may be incurred some years in the future. It is standard practice to discount future costs and calculate the present value of the cost stream. Given the short time horizon of most of our policies, we have chosen instead to sum the unweighted stream of costs.

It is useful for the purpose of comparing reduction strategies to develop a normalized cost measure. In this analysis, we compute costs per ton of CO_2. This is equal to cost divided by the emissions reductions likely to result from a strategy. As with costs, we consider incremental emissions reductions. This is the change in emissions relative to a baseline scenario that results from the implementation of a reduction strategy.

In the second cost estimate, we measure the net impact on the Maine's economy. For the policies analyzed in detail, we utilize REMI, a regional input-output model that simulates the economy wide effects of changes in economic activity in the targeted sector. As discussed, an increase in the purchase of energy saving equipment is a cost borne by the targeted sector. However, the sector of the economy which supplies the equipment to the targeted sector benefits from the policy (i.e., has negative costs). Likewise, the targeted

sector benefits from reduced fuel expenditures over time, yet this is a cost to the sector that supplies fuel. REMI takes into account all of these countervailing effects and measures the net impact on the economy. It does so by way of multipliers that measure how economic activity in one sector stimulates activity in other sectors.

Detailed Analysis of Transportation Policies

In this subsection, we analyze the investment costs and net economic impacts of three strategies designed to reduce CO_2 emissions in the transportation sector. We focus on the transportation sector since it is a large contributor of emissions and, therefore, will likely play an important role in an overall reduction strategy. All policies involve a $0.06 per gallon tax on gasoline spread out over three years. The annual increase in the price per gallon ($0.02) is assumed to have a negligible effect on the volume of gasoline purchased. In 1990, 611 million barrels of gasoline were consumed in Maine. At recent consumption levels, the proposed $0.02 gasoline tax would raise 11.54 million dollars each year in tax revenues.[1] The three transportation policies we consider vary in the way these tax revenues are used to provide incentives for reducing CO_2 emissions. All costs discussed in this section are in current (1997) dollars.

The policies analyzed in this section are chosen primarily for the purpose of illustrating the costs associated with alternative approaches to reducing CO_2 emissions. We show, for instance, that these policies can have positive impacts (negative costs) on the Maine economy. However, before being implemented, it would be necessary to further study and modify these policies.

Van Pools

The first strategy involves cost-sharing for van pools. Gasoline tax revenues would be used to cover one-half the cost of vans and large employers such as paper manufacturers, educational institutions, and government agencies would contribute the balance. Assuming the wholesale price of vans is $15,000, 4,617 vans could be purchased over the course of three years. Costs of administering the program are assumed to be $4,630 per van over the 8-year life of the vehicle, reducing the number of vans in the program to 4,000. If each commuter uses an average of 1 gallon of gasoline per day, average ridership is four persons per van, and there are 250 work days per year, then each van pool reduces gasoline consumption by 1,000 gallons per year. Riders pay for fuel and so their incentive to participate comes from lower fuel expenditures as well as lower maintenance costs on their own vehicles.

Costs of the van pool program are summarized in Table 5. Consumers as a group bear costs of about $35 million as a result of the gasoline tax, but realize $45 million in fuel savings. Employers involved in the van pool program bear costs of $35 million so the targeted sector cost is roughly $25 million. Each van reduces CO_2 emissions by an estimated 80 tons CO_2 over its lifetime, implying that 4,000 vans reduce emissions by 320,000 tons CO_2. Thus, the average cost of reducing emissions with van pooling is $76 per ton CO_2.

The van pooling program also has a direct effect on vehicle sales, fuel sales, and administrative costs. Costs in each of the associated sectors are -$60, $45, and -$9 million, respectively. These costs, along with the corresponding figures for consumers

[1] More precisely, we assumed an annual tax of $0.0189 which raises revenues of $0.0189/gallon × 611 million gallons = $11.54 million

and employers discussed above, comprise the input to REMI. The economy wide impact of the program is estimated at $92 million.[2] This is the amount by which the van pooling program reduces output (or sales) in Maine. The most impacted sectors are paper, construction, and food. The van pooling program is also estimated to reduce employment by about 1,000 jobs. The principal reason for the overall decline in output and employment is that the program shifts money from Maine businesses (the employers who participate in the cost-share program) to businesses outside of Maine (the manufacturers of vans).

It is recognized that the van pooling strategy is ambitious in terms of the number of vans and riders involved. The key to this program is that participants pay only the cost of gasoline and also realize savings from reduced use of their own vehicles. The net savings for participants is assumed to compensate for the added inconvenience of riding in the vans. Nevertheless, to the extent that we have overestimated participation in the program, the cost estimates can be scaled down to reflect a lower ridership. If actually implemented, a van pooling program could supplement existing and successful programs already in effect.

Propane Vehicles

The second strategy involves subsidizing the conversion of gasoline-powered vehicles to propane. The cost of converting a vehicle is assumed to be $2,500, implying that 13,852 conversions can be subsidized with the gasoline tax revenues. Fuel expenditures for the same number of vehicle miles traveled (VMT) are slightly less with propane ($122 per vehicle per year), though maintenance costs are estimated to be somewhat higher ($15 per vehicle per year). Emissions reductions are achieved because propane emits less CO_2 per VMT (1.1 pounds CO_2 compared to 1.3 pounds CO_2). Assuming a 10-year life for vehicles, emissions from a propane vehicle are estimated to be lower by 12.8 tons CO_2. This implies a total reduction from the program of approximately 177,000 tons CO_2.

Consumers bear the cost of the propane vehicle program in the form of higher taxes, which are used to pay for conversion subsidies, and maintenance costs (Table 6). There are some savings related to lower fuel expenditures. The cost borne by consumers is estimated at $20 million, implying an average emissions reduction cost per ton CO_2 of about $113. Other sectors directly impacted are those associated with the sales of conversion units, fuel, and maintenance. The REMI analysis finds that this program increases output in Maine by $40 million and adds about 560 jobs. Retail and wholesale sectors are most affected by the program.

High Mileage Vehicles

The average vehicle in Maine travels 19.2 miles per gallon (MPG) of gasoline. About 31% of the vehicles are compacts or subcompacts, which have an average MPG of 24. The third scenario is aimed at increasing the average MPG of compacts and subcompacts to 30 MPG. This will achieved through subsidies paid to purchasers of vehicles that achieve 30 MPG or higher. An analysis of currently available compacts and subcompacts reveals that the cost of these vehicles falls, on average, by $573 for each 1 MPG increase. Thus, a consumer who switches from a 24-MPG vehicle to a 30-MPG vehicle realizes savings, on average, of $3,438 on the purchase of the vehicle in addition to annual gasoline savings of approximately $132.

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[2] Note that the costs borne by sectors in the Maine economy must sum to zero; however, the economy wide impact may be positive or negative because of multiplier effects and interactions with sectors outside of the Maine economy

Vehicles with lower gas mileage are typically heavier and offer a broader range of features. Through their vehicle purchases, Maine consumers reveal that the savings from owning a 30-MPG vehicle are not a sufficient incentive to buy these vehicles instead of 24-MPG vehicles. It follows that additional incentives will be required to persuade consumers to purchase 30-MPG vehicles. We assume that a $1,000 rebate, provided at the time of purchase, is enough to convince consumers of compacts and subcompacts to purchase higher MPG vehicles. The rebate program would also serve to draw attention to the additional savings from lower purchase prices and fuel use. This program would be available to all automobile consumers, though for the purpose of this analysis we assume that only compact and subcompact consumers participate. To the extent that purchasers of even lower MPG vehicles take part, the emissions reductions will be greater. The program could subsidize the purchase of 34,620 vehicles. Assuming an average 6 MPG increase for these vehicles and unchanged VMT, emissions reductions are 371,000 tons CO_2 over the 10 year life of the vehicles.

Consumers bear the cost of the program in higher gasoline taxes (Table 7). However, the tax revenues are returned to consumers in the form of rebates and savings of $119 and $46 million are realized from lower vehicle purchase prices and fuel expenditures. As a group, consumers derive benefits from this program of $165 million. Sales for motor vehicle and gasoline suppliers decline considerably. The net cost to the state is estimated at -$115 million, implying output increases by $115 million. This result is linked to the shift of expenditures away from automobiles and gasoline, which have low multipliers since they are produced out of state. Instead, consumers have more income to spend on a variety of goods, some of which are produced in Maine. The high MPG program is estimated to create about 1,600 jobs.

Summary

The three transportation programs are estimated to achieve total CO_2 reductions of 868 thousand tons over their lifetime. On a per ton CO_2 basis, the van pool, propane vehicle, and high MPG vehicle programs are estimated to impose targeted sector costs of $76, $20, and -$445, respectively. In the last case, the negative cost estimate suggests that consumers benefit from the program. While it is appealing to think that CO_2 emissions can be reduced and, at the same time, provide benefits to those targeted by the policy, one should interpret this result with caution. It is important to recognize that consumers currently have the option to switch to low MPG vehicles, and, even though this would save them money, they are not choosing to do so. This implies that there are costs associated with switching vehicles — for example, loss of benefits from driving larger automobiles — that are not accounted for in our calculations. We would expect that inclusion of all relevant costs would result in a positive cost estimate.

When we consider the net impact of these policies on Maine's economy, the finding of negative cost estimates (i.e., benefits) is plausible. We estimate costs of –$40 and –$115 million for the propane and high mpg vehicle programs, respectively, and job gains of 563 and 1,1621. The van pool program, on the other hand, imposes a cost of $92 million on the economy and results in the loss of 1,038 jobs.

Table 5. The Costs of Reducing CO_2 Emissions in Maine with Van Pool Subsidies

Costs by Sector	Costs (Millions)
Costs to Consumers	-10
Due to Tax	35
Due to Gasoline Savings	-45
Costs to Employers	35
Cost Borne By Targeted Sectors	25
Cost Per Ton CO_2 (dollars) = 76	
Costs to Motor Vehicle Suppliers	-60
Costs to Gasoline Suppliers	45
Costs to Program Administrators	-9
Net Cost to Maine's Economy	92
Change in Employment = -1038	

Table 6. The Costs of Reducing CO_2 Emissions in Maine with Propane Vehicle Subsidies

Costs by Sector	Costs (Millions)
Costs to Consumers	20
Due to Tax	35
Due to Gasoline Savings	-17
Due to Added Maintenance Costs	2
Cost Borne by Targeted Sectors	20
Cost Per Ton CO_2 (dollars) = 113	
Costs to Conversion Parts Suppliers	-35
Costs to Fuel Sellers	17
Costs to Maintenance Service Suppliers	-2
Net Cost to Maine's Economy	-40
Change in Employment = 563	

Table 7. The Costs of Reducing CO_2 Emissions in Maine with High MPG Vehicle Subsidies

Costs by Sector	Costs (Millions)
Costs to Consumers	-165
Due to Tax	35
Due to Rebates	-35
Due to Vehicle Purchase Savings	-119
Due to Gasoline Savings	-46
Cost Borne By Targeted Sectors	-165
Cost Per Ton CO_2 (dollars) = -445	
Costs to Motor Vehicle Suppliers	119
Costs to Gasoline Suppliers	46
Net Cost to Maine's Economy	-115
Change in Employment = 1621	

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